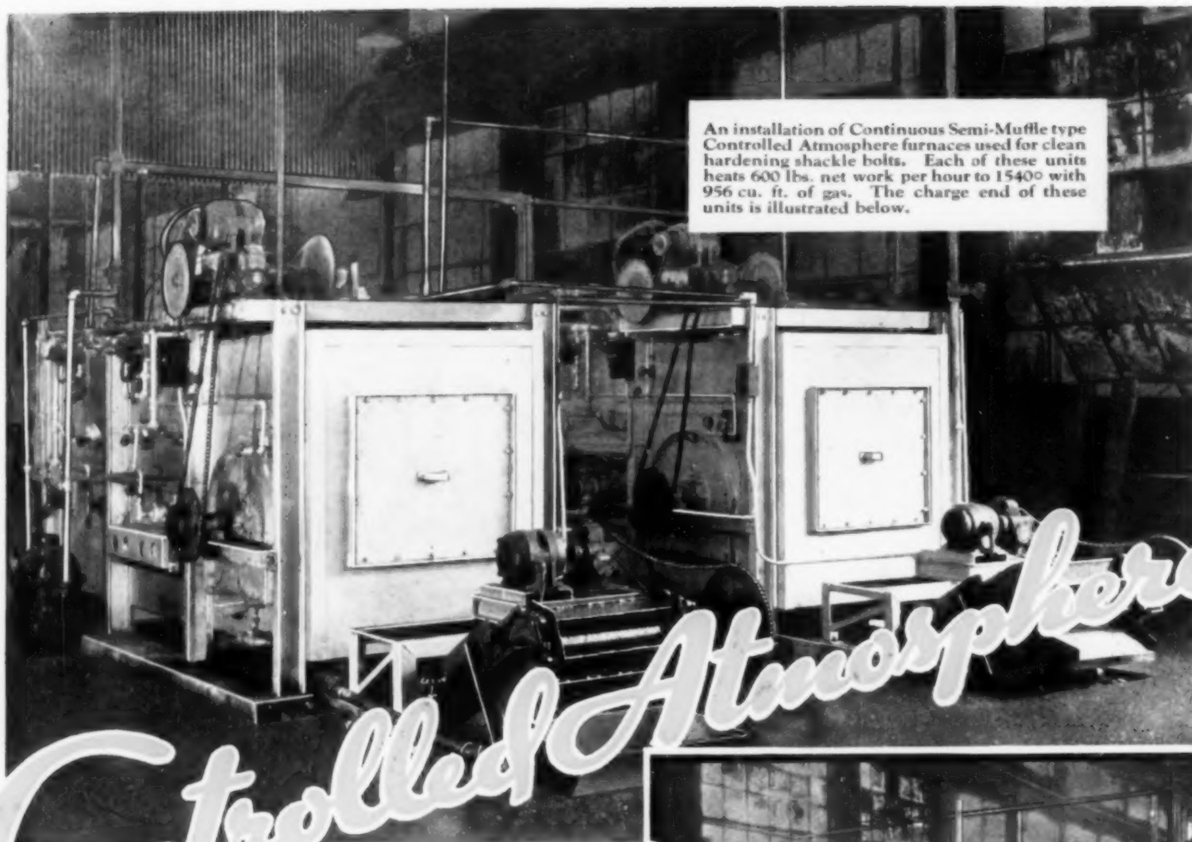
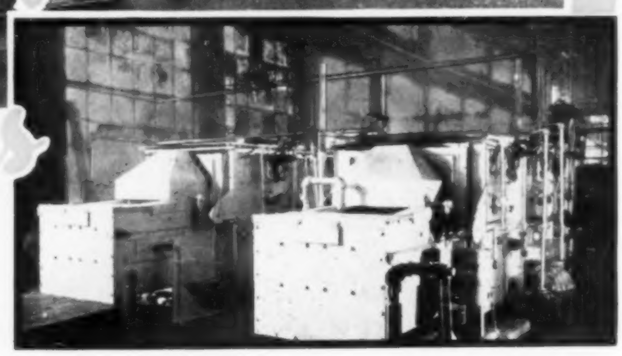
METAL PROGRESS



An installation of Continuous Semi-Muffle type Controlled Atmosphere furnaces used for clean hardening shackle bolts. Each of these units heats 600 lbs. net work per hour to 1540° with 956 cu. ft. of gas. The charge end of these units is illustrated below.

Controlled Atmosphere Furnaces



Controlled Atmosphere Furnaces are being used for bright annealing of ferrous and non-ferrous metals — for clean hardening, nitriding, and gas carburizing of steel. SC Furnaces for each of these processes are available for continuous or batch operation. All of these processes have been pioneered, developed and made commercially practical by SC engineers. These same engineers will be glad to go over details with you, pertaining to your problems. Perhaps the solution may involve the application of only minor equipment.

Also makers of a complete line of Standard Rated Furnaces and Standard Burner Equipment. There is a correct size and type SC Standard Furnace for any heat treating operation. Correct Burner Equipment can be selected from a line of more than 16 different types and over 400 different sizes of burners.

Another S. C. Continuous Controlled Atmosphere furnace installation. These two units are doing better clean hardening and doing it more economically than it was done with the previous equipment. . . . . . . Each installation of S. C. Continuous Controlled Atmosphere furnaces contributes to an already generous experience gained since S. C. engineers first developed the continuous process of bright annealing of ferrous and non-ferrous metals; gas carburizing, clean hardening, nitriding and forging of steel. . . . . All this experience is available to you to help improve quality and effect economies in your heat treating operations. Let our engineers help you with your problems.

Surface Combustion Corporation

TOLEDO, OHIO — Sales and Engineering Service in Principal Cities

METAL PROGRESS

table of contents

January, 1934
Volume 25, No. 1

. . . . Above is a rare likeness of a well-known and well-liked metallurgist—none other than Harry W. McQuaid, the world's most camera shy individual! It takes a major event to get such a photograph, such as a change in position from chief metallurgist of Timken-Detroit Axle Co., to Chief of Research and Development for Republic Steel Corp., or the publication of a leading article in Metal Progress . . . . His article on page 15 is based on a recent address before the Pittsburgh Chapter, and is written from the consumer's standpoint, yet with full knowledge of what the steel man is up against in providing uniformly high quality—for in years gone by, he was metallurgist of Timken Roller Bearing Co., and with Mr. Ehn, worked out the well-known McQuaid-Ehn test for measuring the quality of steels . . .

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Ernest E. Thum, Editor.

MODERN MACHINERY CALLS FOR MODERN METALS

ALLOYS CONTAINING NICKEL...

HELP TO WING YOUR MESSAGE TO EVERY PART OF THE GLOBE

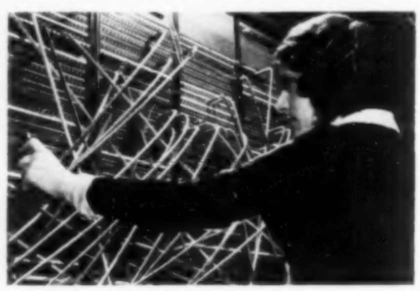
SEATED comfortably in your living room you turn the dial of your radio... And out of the Antarctic dusk comes the voice of Admiral Byrd. Close your eyes and he might be just across the room.

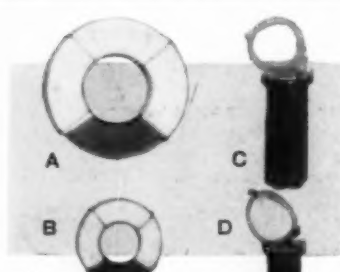
In your office the telephone rings. And with all the clarity of a local call, your Paris representative talks to you across the Atlantic.

By telegraph... and by cable... messages flash to the farthest corners of the globe, dispatched at a speed and volume that a decade ago would have seemed fantastic.

And helping to work all these miracles of present day communication is a versatile group of modern metals... alloys containing Nickel.

Alloys containing Nickel speed up transmission by increasing the message-carrying capacity of the cable. They form the cores of radio audio transformers and important parts of the screen grid tube. They form the cores of telephonic and telegraphic relays, and important parts of receivers, earphones, transmitters. In fact, there are dozens of applications in the communication field where alloys containing Nickel are used.





PERMALLOY... A highly magnetic Iron-Nickel Alloy containing up to 80% Nickel. Widely used for electrical sheathing of submarine cable, radio transformers, telephone and telegraph relay parts... Pictures above show the saving in space effected by the use of Permalloy loading coils compared with powdered iron. *A*—powdered iron coil. *B*—Permalloy coil producing same loading effect. *C*—Case potting of 200 powdered iron coils. *D*—Case potting of 200 Permalloy loading coils.

Their use, however, is by no means confined to this field. Alloys containing Nickel are widely employed today in every industry where machines require metals of greater endurance and greater dependability.

When Nickel is correctly alloyed with other metals a wide range of improved properties is obtained—properties that assure increased resistance to the destructive forces of heat, stress, fatigue, erosion, corrosion, abrasion and wear.

Hence when equipment is thoroughly modern you are certain to find Nickel Alloy Steels, Nickel Cast Irons, Nickel Bronzes, Stainless Steels, etc., serving a wide range of purposes.

Alloys containing Nickel are commercially available *in a variety of compositions* in all important metal consuming centers. If you are planning to build new equipment or modernize the old, our engineers will be glad to advise you concerning the most suitable applications.

THE INTERNATIONAL NICKEL COMPANY, INC.

Miners, refiners and rollers of Nickel. Sole producers of Monel Metal.

67 Wall Street New York, N. Y.

Bar Mill Run Out

One of a Series of Etchings Made by Otto Kuhler for Timken Roller Bearing Co., and Reproduced by Their Courtesy

TREND IN REQUIREMENTS

for plain & alloy steels

by H. W. McQuaid
(For Biographical Note
See Page 1)

ONE OF THE MOST IMPORTANT changes in the steel trade which has taken place in the past ten years (as far as the steel maker is concerned) has been in the consumer's ideas as to the responsibility of the steel maker for results in the fabrication processes, especially machinability and response to heat treatment.

Ten years ago the four most important specifications for forging billets which were intended for heat treated parts were:

1. Analysis
2. Size
3. Surface
4. Soundness

It was assumed by the buyer that if the mill shipped steel which was of the specified analysis and size, and was sound and had good surface, the steel maker had met his obligation. Size, surface, and soundness were historic requirements. Chemical analysis was much more recent, and the conception of its particular importance resulted in very strict insistence on chemical specification, with many rejections because of slight variations from the prescribed limits in carbon or other elements.

In the Detroit district (which is most familiar to the writer, and may be taken without undue conceit to represent a progressive metallurgical region) chemical analysis was a criterion by which all grades of steels for heat treating were rated. Ten years ago the chief metallurgist of a large automotive company informed me that if any of his subordinates would take it upon himself to accept a heat of steel in which the carbon exceeded the specified range by one point, he would be dismissed! This, of course, was an extreme view, and yet many heats of perfectly satisfactory steel were rejected because of some minor variation in chemistry. Many other metallurgists realized that there was some permissible extension of the limits for most of the elements specified and would, when consulted by the steel supplier, accept heats outside of the specified limits of analysis.

Because of this insistence on strict chemical analysis and the importance given to it by the customer, the chemist grew into a more and more responsible position in the steel plant, particularly in the eyes of the sales department. Yet, due to the fact that the chemistry of a finished heat is relatively easy to control, the melter, chemist, and metallurgist had not ar-

rived at the exalted position in the mill which fell to the lot of the roller. Because of the insistence on size specifications and surface requirements, and also due to the fact that most of the complaints by the customer concerned size and surface, the sales department was inclined to look upon the head roller as the most important man in the operating department and of the most influence on their problem of shipping steel which would result in a very minimum of rejections and complaints because of variation in size or surface.

> *Large consumers of plain and alloy steel now reject any shipment which machines poorly or heat treats unsatisfactorily. This has given the steel plant metallurgist new importance in an effort to produce steel which responds uniformly, heat to heat, in these important respects.*

During all this time, every plant in the consuming industries which was heat treating steel on a large scale endured a continual variation in the results in quenching and in normalizing, and frequent complaints from the machine lines because of poor machinability. Much attention was given to furnaces, control, quenching equipment, and other details of the operation, and the position of the plant metallurgist became of considerable importance because of the necessity for reducing the rejections in the heat treating department. This general situation also led to an increase in the use of alloy steels in order to secure more uniformity in the finished product — and because of this we have today many parts made from alloy steel for the sole reason that by their use it is possible to obtain consistently dependable results in the finished part.

It is well known that this change in equipment and technique led to a far better, more uniform product. Nevertheless, despite the improvement in furnaces, pyrometer equipment, quenching equipment, and the use of alloy steels, there still arrived, occasionally, heats of steel which varied considerably in hardening qualities and machinability, despite a good analysis, cleanliness, and normal physical properties.

It was recognized that certain heats of steel, followed through to the finished part, behaved differently in heat treatment and machinability, and this resulted in the practice of keeping heats separate through the heat treating department — a procedure which should be followed by every up-to-date and well-controlled plant. If each heat is kept separate, it will soon become evident that individual heats, even though of the same analysis and from the same type of melting furnace, will vary unmistakably in such important properties as machinability, distortion, and depth of hardening.

This difference, heat to heat, became quite a problem to men who were making war munitions in 1916, '17 and '18. At that time there was little opportunity to get at the root of the trouble, and only in the last few years has it gradually become evident that in spite of the best equipment, normalizing practice, and other factors in the manufacturing plant, many of the troubles due to distortion, poor machining, and inferior physicals were without doubt the direct result of some variation in melting practice. It has finally become quite clear to those at the consumer's end that a specification, to be satisfactory, must cover in some way these variations, heat to heat.

To a large degree this has been the function of the "grain size" test, proposed some years ago by Mr. Ehn and the present writer, and now insisted upon by the large users of steel designed for heat treating. This, as well as the growing demand for good machinability, has caused an acute situation in those steel mills which furnish alloy and high grade carbon bars, a situation met only by an entirely new line-up in the comparative authority of melter, roller, chemist, and metallurgist.

Specific examples taken from the Detroit district will be illuminating. On such parts as use plain carbon-manganese steel, some factories required steels which were shallow hardening to avoid cracking in quenching, while for other parts made of the same type of steel the material must be deep hardening to obtain suffi-

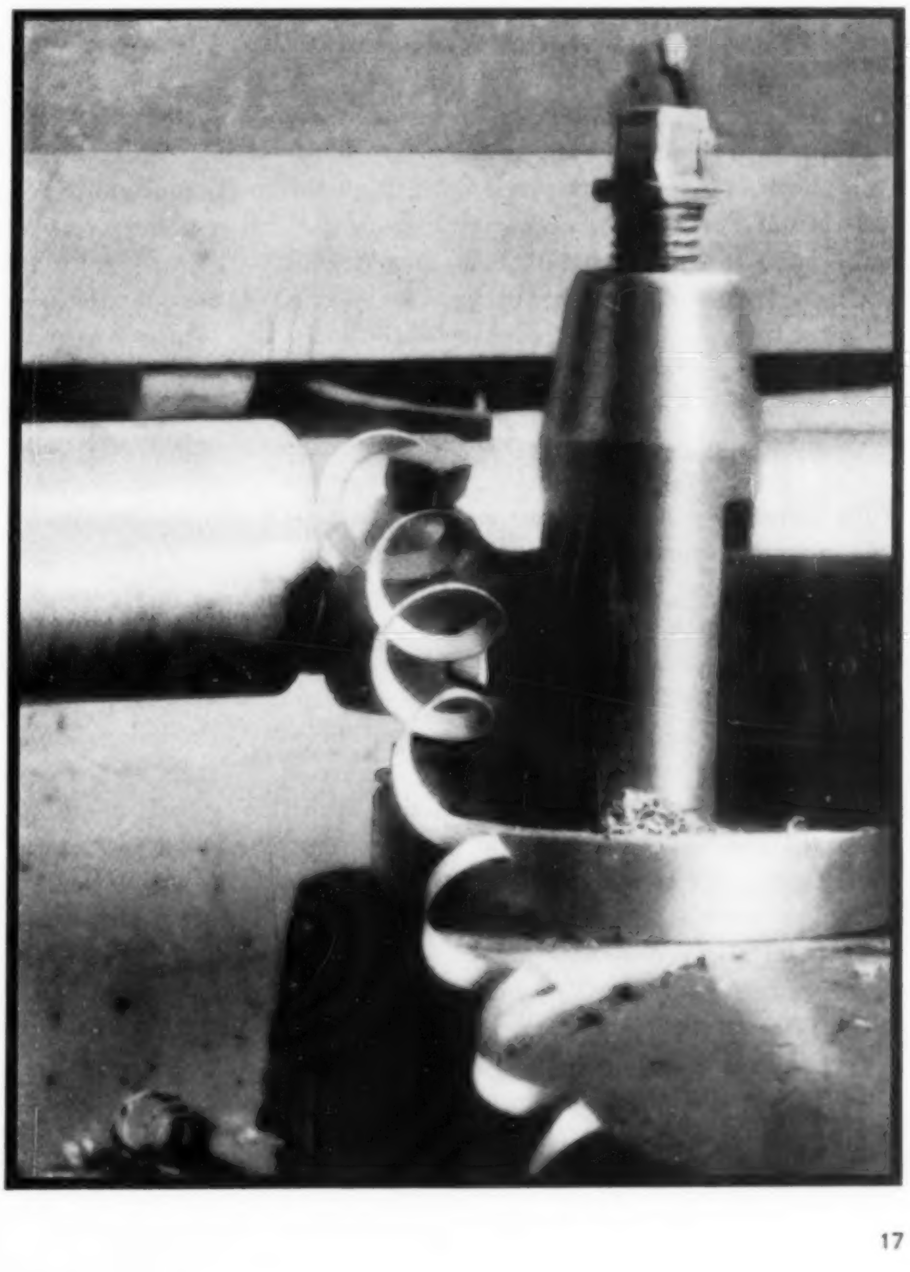
cient depth of hardness to meet the physical properties. Some items, such as starter rings (which were normally oil quenched and made from plain carbon specifications) needed the maximum of hardenability in order to meet the required Brinell hardness.

Steel Sold on Performance

Steel companies which had supplied material for such parts as front axle centers, cranks, or connecting rods, lost their business (if they could not control the hardenability of their plain carbon bars) to those producers who were able to furnish shallow hardening bars where this characteristic was needed, and deep hardening bars where this requirement was most important. Many actual instances could be cited of this transfer of accounts because of the inability of one steel maker to supply a satisfactory product to his customer. Of course, these changes were beneficial to those progressive steel companies which were advancing their melting practice to give the customer what was needed.

Thus, the automotive industry and other large consumers of both plain carbon and alloy steel have now arrived at the point where their technical men expect the steel maker to supply metal to them which will react in a certain way when heat treated in modern, automatically controlled equipment, and it is demanded that this reaction be uniform from day to day and from heat to heat. This means that the steel producer must introduce accurate metallurgical control into his steel making process, train melters, and develop a technique which permits him to vary at will the depth hardening characteristics and grain growth characteristics of each heat of steel.

The steel maker is also expected to produce alloy steels for carburizing which will show practically no grain growth or distortion after quenching directly from the carburizing box. It therefore becomes necessary to control the melting practice for the carburizing grade of alloys, so that the distortion in hardening caused by variable quenching rates in different parts of a machined piece will be at a minimum.



Chips Like These Are Fine for Camera Men, but Bad for Automatics. Photo is by F. H. Semple, who calls it "Permanent Wave"

At the same time the steel user is interested in obtaining the maximum rate of machining, despite his experience that this will vary considerably from one heat to another, even after a uniform normalizing practice. It has been discovered that this variation in machinability is primarily due in good part to different rates of grain growth in the different heats of steel.

It is apparent that the effect of the normalizing operation — which tends to produce the maximum grain growth for easy machinability — may be completely lost if the steel resists grain growth at normalizing temperature. Here again the grain size test is commonly used, and it is customary to specify the coarser grained steels in order to obtain easy normalizing for the best machinability.

Contradictory Requirements

Here arrives something of a dilemma. Since the coarser grained steels are usually deep hardening and tend to distort much more than the finer grained steels, it is necessary for the steel maker and the plant metallurgist to arrive at a depth hardening and grain growth specification which will give a commercially satisfactory product from the standpoint of distortion, and at the same time one that will machine at a satisfactory rate. The net result of this is that specifications now in force have become quite narrow in their tolerances, and the steel maker is again faced with the necessity of either selecting special heats or going beyond commercial extremes in his melting shop practices to satisfy the customer.

As an illustration of present-day occurrences, it may be stated that one of the large buyers of alloy steel for automotive gears is requiring heats which, after normalizing by his standard method, will result in a given number of gears per tool grind, and is selecting his source of steel according to the degree of success which a given vendor has in meeting this specification!

It is quite evident, therefore, that a new day has dawned in the making of alloy and fine steels which are to be machined or heat treated. Responsibility for the results is being placed directly upon the steel maker. If, in addition to this responsibility, specifications are added covering cleanliness, transverse impact, physical properties, special ductility, bend tests, and so on, the necessity for much metallurgical development and supervision in the steel business is quite evident.

Some steel companies now advertise that they have this situation well in hand for plain carbon bars. By means of very carefully worked out metallurgical supervision of melting practice, others are meeting these special requirements with reasonable satisfaction. Still other steel producers, however, are entirely ignorant of even the necessary method of attack to develop the necessary control, and some who know in a general way what to do are unable to obtain the necessary control in a commercial operation. The last-mentioned companies will, of course, suffer greatly in the race for those markets which demand that the steel maker be responsible for the way their product acts in a customer's factory.

This race has reached the point where it is too late to turn back. The net result will be a great improvement in the uniformity of steel as made, and at the same time a great improvement in the results achieved by the consumer. While it may seem that the plant metallurgist is unfair in his demands that the steel producer accept the responsibility for difficulties in a customer's factory, results have indicated that the plant metallurgist is in most cases taking the right stand.

Precise Specifications Needed

In order that the steel company may avoid assuming a blanket responsibility for all his customer's difficulties in obtaining uniform results in machining and heat treating, every effort should be made to define exactly just what is wanted, and to develop some means of testing whereby the steel maker can determine, before his product is shipped, how it will react in a correct heat treatment and in proper machining. This new development in specifications will require much cordial cooperation between metallurgists representing both sides of the question — a cooperation which past experience leads us to expect will be forthcoming in this most important forward step.

CONCENTRATED STRESSES

in welded structures

by Robert E. Kinkead
Consulting Engineer, Welding
Cleveland

SELDOM DOES A MACHINE PART OR a member of a structural assembly fail from what is commonly known as an overload; the characteristic necking of a tension test specimen is almost never seen. Failures start at points of maximum stress concentration and proceed by tearing to a complete rupture.

This situation has led to a new approach to problems of structural design, using the term "structural" in its broadest sense. Particularly, the designer should consider stress distribution in welded structures, in addition to approximations of *average* stress found by conventional formulas.

Stress concentrations commonly occur from three causes, (*a*) change of contour of the stressed member, (*b*) residual stresses from the welding operation, and (*c*) defects within the metal, such as gas pockets, slag inclusions, or failure of fusion. It is proposed to deal here primarily with the first two, which need careful study, for neither is allowed for when using conventional formulas.

Factors of safety from 4.0 to 10 have been commonly used to bridge the gap between the computed average stress and actual maximum stress in a structural assembly. We are now fully aware that substantial economies may be effected by substituting *information*, when it can be obtained, for arbitrary safety factors which may or may not be large enough.

Stress concentrations due to change in contour may now be predicted with a satisfying degree of accuracy. Stress concentrations due to residual strains are gradually being brought within the field of predictable phenomena, and methods have been developed by which they, if unknown, may be reduced to negligible value.

Concentrations Due to Contour

The simplest illustration of the necessary reduction in working load due to stress concentrations is a bolt loaded in static tension. Made of a material having an ultimate tensile strength of 65,000 lb. per sq.in., a bolt has an allowable working load of 5180 lb. when the area is one square inch. The safety factor is about 12½. Subject the same bolt to impact or rapid reversal of stress, and the working load might properly be reduced to 2000 lb. per sq.in. This would mean a safety factor of 32½. This situation is brought about by stress concen-

trations at the root of the threads, an unavoidable consequence of sharp changes in contour.

Thus it is not an academic matter. Stress concentrations are also acute in fillet welds on lap joints subjected to transverse loading. The sketch at right (below) shows a model of two lap welds on a joint in ¾-in. plates. Due to its contour, the stress in weld *A* at point *3* is roughly six times the average stress in the plate at some point such as point *1*. Improvement of the contour to the most perfect curve that may be designed, such as in weld *B*, results in a stress at point *2* of possibly 2½ times the average. This is readily determined by pulling the rubber model and measuring the elastic changes in the original square rulings. It is true, of course, that these stress concentrations are peculiar to lap welded joints and the contour of the fillet affects the size of the maximum stress, but the shape of the lap joint itself results in stress concentrations of approximately 2½:1 with the most perfect weld fillet that may be designed.

Engineering formulas give average values for stress carried in various members but failures are often due to concentrated stresses at some change in contour or internal defect. Residual stresses due to welding heat cycle are also insidious causes of failures in service. Methods avoiding these troubles are discussed.

A Specific Case

Translating this into the field of practical design, we may consider such structures as hull plating for ships, members of bridges, machinery and equipment parts carrying live loads, or, as more properly described, dynamic loads. Assume material with 70,000 lb. per sq.in. ultimate stress and a 15,000 lb. per sq.in. working stress. At a bad fillet *A* we would have an *indicated* stress concentration of 90,000 lb. per sq.in. and 37,500 at the good fillet *B*.

At the first application of the full working stress to the sections having uniform stress distribution, the metal adjacent to the bad fillet might carry some such stress as 50,000 lb. per sq.in., which is beyond the yield point and endurance limit. In the case of the good fillet, the yield point might not be reached. So far as static loading is concerned, nothing serious has happened, or is likely to happen. But repeated loadings of such intensity will result in premature failure. The life of the metal at point *3* under such conditions is not measured in terms of millions of load cycles, but only in terms of hundreds.

It is obvious that lap welds subjected to dynamic tension loads are dangerous and uneconomical.

Some remarks are in order relative to the statements made above about an *indicated* stress of 90,000 lb. per sq.in. and an *actual* stress of perhaps 50,000 lb. at point *3*. The explanation will disclose the lack of precision of our present knowledge.

The degree of stress concentration on a section of known contour is determined approximately by use of the photo-elastic method of stress distribution analysis, use of rubber models, hard varnish which cracks at known degrees of strain, and other devices. The first-mentioned has been frequently described, and the photograph on page 22 indicates the image given by polarized light shining through a loaded model of transparent material like bakelite. But any of these methods gives information only within the elastic range. In the case cited above, a stress concentration of 6 to 1, on 15,000 lb. per sq.in. calculated average stress, gives a maximum stress of 90,000 at point *3*, yet we have assumed the ultimate strength of the material to be 70,000 lb. per sq.in.

We do not know, quantitatively, how a section of ductile, low carbon steel would behave under such a condition of stress concentration, but we do know qualitatively. As the stress at point *3* passed the yield point of say 40,000 lb. per sq.in., the metal there would yield plastically, and redistribute the stresses. Below the yield point, the degree of stress concentration obtained by analysis would be correct. But stress concentrations which result in plastic

deformation of metal have passed beyond the range of quantitative prediction.

We know that if the maximum stress goes but slightly beyond the yield point, plastic deformation sets in without further increase in stress, and this change in the metal might be sufficient to reduce the stress concentration very greatly — conceivably to zero. In the case of a sharp notch, on the other hand, the length of the increment of metal deformed plastically might be so short as to have very little effect in rearranging the internal configuration of the metal and decreasing the degree of stress concentration. Under these conditions, the maximum stress might be anything up to the ultimate strength of the metal.

In the design of welded structures, contours must be used which keep the maximum stress well below the yield point under the worst conditions of service loading.

Residual Stresses

Application of a welding heat cycle leaves residual stresses in or adjacent to the weld; the intensity may be negligible, or may be sufficient to cause failure before *any* useful load may be applied. In this respect, residual stresses differ from conditions described above in which the stress concentration does not occur until an external load is applied. But the net effect, from the engineering point of view, may be substantially the same, and results in loading far above the yield point which, under dynamic loading, means premature failure.

Local application of high temperature to cold metal results in local expansion and contraction. Residual stresses are set up if there is any restraint to such movements. Thus, if a bar is heated uniformly, and then both ends are securely fixed to prevent contraction, approximately 200 lb. per sq.in. residual stress will be generated for every degree it cools. With the ends free to move, no important residual stresses would be developed other than those arising from a temperature gradient between the surface and interior of the bar. In a bar of small sectional area, such stresses would be negligible although in a bar of large sectional area, such residual stresses might be of high value.

The case of a welded seam in steel plate represents a problem far more complicated than the above, and we are again limited to a qualitative analysis. But there is ample justification for this, since if we do not know how and why residual strains are left by a welding heat cycle, we cannot proceed with methods for their control or reduction to safe limits.

A long seam progressively welded with the electric arc process illustrates a good many of the principles involved in all types of welds. The sketch on page 23 is a plan of a welding operation started at *A* and proceeding toward *H* at some low speed, such as 15 ft. per hr. In order to take into account the whole heating and cooling cycle, it is assumed that the seam is of sufficient length that by the time

Cross-Section of Lap Joint Made in ¾-In. Plates Ruled in 0.10-In. Squares. If model is stretched, elastic deformation at a small bead (point 3) is much higher than at a well-designed bead (point 2)

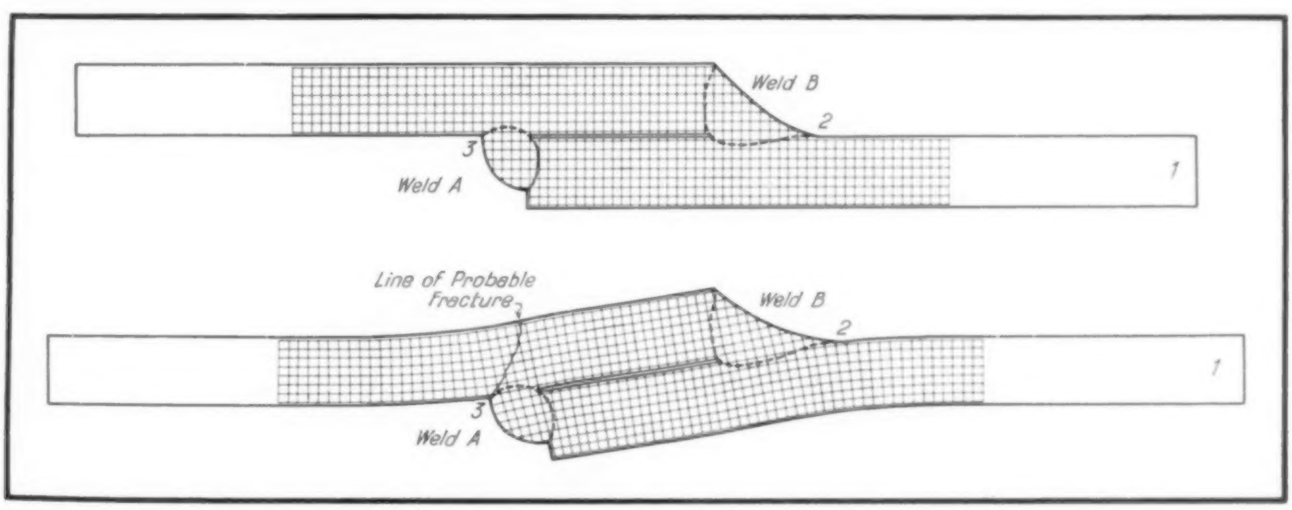


Photo-Elastic Model Is Made of Transparent Celluloid and Photographed in Polarized Light. Model is of a butt joint, welded at edges only, and shows high stress concentration at ends of internal slot. In a hard, stiff weld, shown at left, failure is by tearing at end, as indicated by model. If weld is ductile, plastic deformation will cause redistribution of stress, and failure occurs in a way not predictable by photo-elasticity. Photograph by Everett Chapman, vice-president, Lukenweld, Inc., Coatesville, Pa.

point H is reached, point A has returned substantially to ambient temperature. It will further be assumed that the weld is made at one pass, and the plates (½ in. thick) are free to move in any direction.

Conditions at section G may advantageously be considered first, where the welding heat has been recently applied. The approximate temperature gradient is shown by the heavy curve with horizontal through G as a base. The weld is still at high temperature Tg but is rapidly cooling by conduction into the adjoining cool plate, and also by radiation and air convection, and therefore the center of the weld is always contracting. At points g_1 and g_2, the temperature is rising, due to a flow of heat from the high temperature at the center of the weld into the cool surrounding plate, and consequently the metal is expanding at such points. The resultant along line g_1-G-g_2 is a high degree of contraction, due to the rapidity with which the very high temperature weld loses temperature by radiation.

Proceeding back along the weld to section F, a different set of conditions is found. Sufficient time has elapsed to permit a greater flow of heat from the weld to the plate. A considerable amount of metal in the dimension transverse to the direction of the weld, which was cold, is now at an elevated temperature. The weld itself is no longer cooling so rapidly by radiation, although it is still losing temperature by conduction. The resultant at section f_1-F-f_2 is expansion. Expansion here and contraction at g_1-G-g_2 tend to pull together the edges of the seam ahead of H (a commonly observed phenomenon).

(But it should not be considered as an inevitable occurrence. If the welding arc advanced at four or five times the speed we have assumed in this case, the edges of the plate would tend to open instead of close. In the latter case, a considerable length along the weld is at a high temperature and the resultant expansion along the edge of the plates in a direction parallel to the motion of the advancing arc is sufficient to overcome the contraction occurring at right angles.)

The temperature gradient at section E is the point of equilibrium. Here, loss of heat by radiation and convection has stopped the flow of heat to points e_1 and e_2.

From section E back to the beginning A, which we assume to have reached ambient temperature, there is a gradual fall in all temperatures within the area under consideration by radiation and convection losses, and with this fall in temperature comes a second contraction. This is the contraction of the base metal, the first being a contraction of the weld metal in the joint. It may be greater or less than the first. The sum of the two may be anything up to the ultimate strength of the metal at a critical location. As the cold ambient condition at A travels to B, C, D, E, F, G, and H, the original tendency of the plate edges ahead

of H to come together is accentuated. Transverse warping is thus accounted for.

So far, we have considered contractional forces in only one of the three physical dimensions of the plates. As the cold ambient condition of section A travels to H, longitudinal stresses are also set up. For instance, reduction of temperature from section A to C results in contraction and this length of seam and plate gets shorter. The plates buckle to some degree under the longitudinal stresses built up in this manner, since a ½-in. plate has a negligible degree of stiffness.

The third physical dimension, thickness, also plays a part in the final condition of warping and buckling. In the ½-in. plate under consideration, the top of the weld would always cool *after* the bottom, resulting in higher stress in the top. Thus, any tendency toward warping in the dimension transverse to the seam would always be accentuated by higher stresses in the top side of the weld, moving the plates so that they are concave from the top side.

Starting with two flat plates which were free to move, we have welded them progressively together. The plates are now warped and buckled; even so, they may have high residual stresses in and adjacent to the weld. Had the plates been a part of a structure in which they were not free to move, the residual stresses would have been higher, although the warping might have been very small.

A serious engineering dilemma is thus created. If warpage is prevented, dangerous residual stresses exist which may give trouble even before the structure is loaded in service. If a warped structure relatively free from residual stresses is loaded, dangerous stress concentrations (due to contour) are certain to be induced when it straightens out. Even if the warped assembly is stress relieved by heat, the shape will not be changed, and when it is loaded the same stress concentrations due to contour will be introduced.

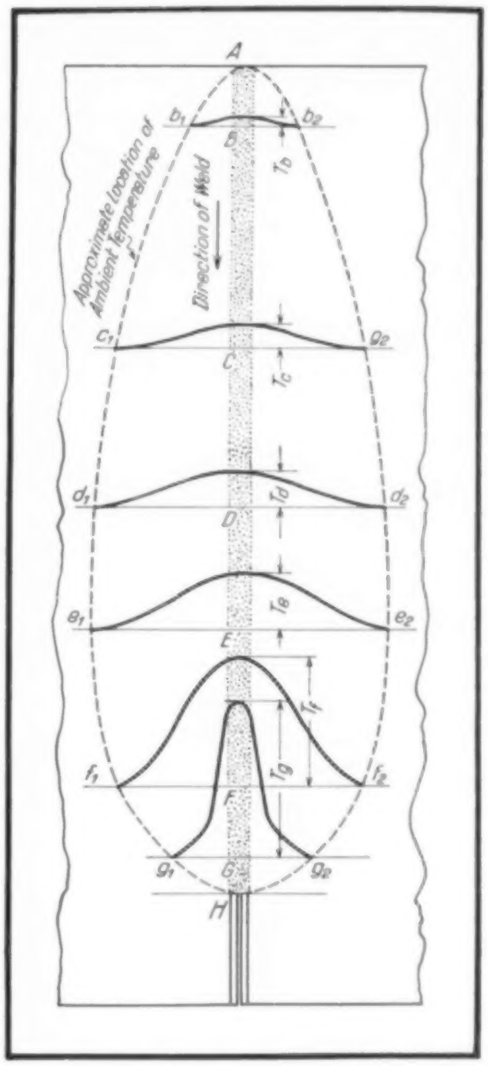
The way out, from the viewpoint of engineering practice, involves the whole field of procedure and technique in the applications of welding. But it should always be remembered that no welded structure is safe in which metal in any region is subjected to dynamic loading above its yield point. To put such structures into service is to invite death, destruction, and disaster.

Relief of Stresses

In the limited space of this article, the methods of bringing residual stresses to negligible value will necessarily have to be touched on lightly.

The first step is to adjust the welding sequence so that the smallest possible residual stress is set up. Among the methods used are step-back welding, alternate welding on one side of the plate and then on the other, preheating the parts, use of copper chill bars to restrict the flow of heat, and peening the weld metal. Failing in these measures, only two methods are known of treating the structure to assure that damaging residual stresses do not exist. One method is to load the structure up to the approximate proportional limit of the metal. The other is to heat the structure to 1100 to 1200 F.

The first method is analogous to flattening sheet or thin plate in a



Long Seam in ½-In. Plate, Showing Approximate Temperature Gradients at Different Sections Transverse to Weld

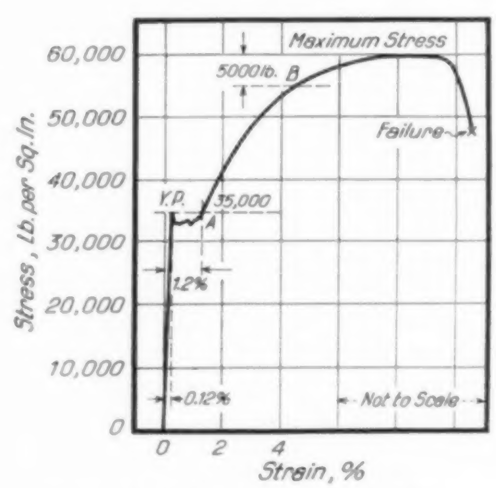
stretcher or a roller leveler. To explain the method, the stress-strain curve of a good steel for welding purposes is shown below.

From the origin O up to the elastic limit (assumed to be very close to the yield point $Y.P.$), the stress-strain relation is linear, and if unstressed metal is loaded to 30,000 lb. per sq.in. (below the elastic limit) it will stretch a certain amount, but this elastic movement will reverse itself when the load is relieved. In fact, any load up to the elastic limit will cause no change in the metal other than that due to the load itself and is permanent only as long as the load is permanent.

Now assume that the welded structure is carrying an internal stress at some point equal to 10,000 lb. per sq.in. in tension. When the structure is loaded to 25,000 lb. per sq.in. by external proof load, this spot reaches the yield point and plastic flow starts, and the stress-strain curve shows that this metal can be extended about 1.2% to point A before the load can get any higher than the yield point.

It is apparent that if we apply a load of 30,000 lb. per sq.in. to the structure, we may be sure that any existing residual stresses larger than 5000 lb. per sq.in. will be "pulled out," and when the load is released they cannot exceed the difference between the yield point and the proof load (in the case of a 30,000 lb. proof load, 5000 lb. per sq.in.).

The characteristic of the metal shown on the curve is extremely valuable in this operation. Thus, the elongation up to 30,000 lb. per sq.in. will be the proof load divided by the modulus of elasticity, or $30{,}000 \div 30{,}000{,}000 = 0.001$ or 0.1%. The elongation from the proportional limit to the point A on the curve may be 10 or even 20 times that amount, and most of it occurs between the true yield point and the point A without additional load being applied.



Typical Stress-Strain Curve in Tension of Mild Steel Suitable for Welding

However, it is possible that in or adjacent to the weld, we have plastic deformation to such a degree that the metal has already passed point A and has arrived at B just prior to application of the static loading for residual stress removal.

Assuming that B is within 5000 lb. of the maximum strength, application of only 5000 lb. per sq.in. static loading will load this spot past the peak and failure will result. This serves as a test of the structure and is desirable for the reason that it is much preferable to have the structure fail on test rather than after it has been in service.

Where possible, the structure can be stress relieved in a furnace by heating to 1100° to 1200° F. It is known that the yield point of steel is very low at these temperatures, and any point in the metal which has a total stress from any source which is above that new yield point will "creep" enough to relieve it.

It should be kept in mind that we are dealing with this subject from the more or less practical viewpoint of the engineer. In neither case have we relieved internal stresses as disclosed qualitatively by the X-ray diffraction method of analysis. Nothing short of complete recrystallization by heating above the upper critical (say to 1750° for mild steel) can completely stress relieve the metal after it has been through the welding heat cycle.

Premature Failures

To summarize, stress concentrations which result in stresses above the yield point during dynamic loading in service are dangerous and lead to premature failure of the structure. Such stress concentrations are likely to occur from defective weld contours, failure of fusion, discontinuities of any kind, or from residual stresses arising from application of the welding heat cycle. Unrelieved stress concentrations from any cause are insidious; they do not cause immediate failure, but may result in premature failure of the "fatigue" type when the structure is believed to be safe because it has a service record.

"FIRELESS" SALT BATHS

heated by resistance

by A. E. Bellis
President, Bellis Heat Treating Co.
Branford, Conn.

MOLTEN LEAD OR SALT AND SODA baths have been used for heating fine tools, wire, and springs for many generations. More recently — perhaps within 40 years — since cyanide has become relatively cheap, a pot full of melted cyanide has become a useful hardening medium. Therefore, a long experience with the art has proved the advantages of such heating mediums — the pieces are heated at all points at a uniform rate and the surface comes out bright and unscaled. These factors are of special importance for intricate tools or small, thin articles.

Difficulties began to appear when these molten baths were pushed to the high temperatures needed for some steels — say, 1600° F. or over. The lead oxidized and the salts fumed too rapidly. The far higher heats necessary for high speed steel were out of the question until special salt mixtures were discovered that were stable at white heat. While work along these lines is still in progress, it may be said that successful formulas were devised about 20 years ago.

This led to another problem in connection with the pots or containers. It is one thing to immerse a bundle of small articles in a hot salt bath for a few minutes and find their surface unattacked, but another to build a steel or alloy pot to resist this hot salt for hundreds of hours — hot salt on the one side and hotter furnace gases on the other. Any hot spot where the flame might impinge was quickly eaten through (and it is almost impossible to get uniform heating in a fuel-fired furnace setting). These furnace difficulties have discouraged many who have real reason for using salt baths in their heat treating operations.

Alloy steel makers and furnace builders have both contributed to a solution of these remaining difficulties — the one to produce a heat resistant and salt resistant metal, and the other to devise a method of internal heating, so the pot itself cannot get hotter than its contents. Salt bath furnaces over 20 ft. long now are successfully handling tons of metal parts an hour with no appreciable depreciation of the pot. The same permanence of smaller alloy pots is reported where the operating temperature is 2350° F.

The plan of heating the salt bath by passing an electric current through it was tried first in high temperature baths used for hardening high speed. Instead of using two parallel electrodes, the pot itself formed part of a heating circuit, which was completed through an elec-

trode immersed in the bath. This gave more working room in a smaller pot than when two electrodes were present, and a smaller pot meant less radiation from the top when it was uncovered. In fuel-fired furnaces the smallest possible pot had been used to reduce the cost of renewals, and quite expensive pressed or hot forged pots were necessary. With the new method of heating it is possible to use high grade castings of analysis quite suitable for the service but incapable of being forged. Even with greatly increased pot life, it still is desirable to use a small pot for high temperature work because of heat economy.

Externally heated pots for lead or salt baths frequently fail where a swirling flame overheats a spot. Internal heating by means of submerged electrodes avoids this difficulty; the pot is now cooler than its contents. Resistance of the molten salt is low, thus reducing danger from short circuits through the metal being heated.

With steel pots in fuel-fired furnaces nickel and nichrome pyrometer tubes were satisfactory; this led to the trial of pots made of these metals. Invariably an electrolytic effect on high speed steel tools resulted. This proved to be due to nickel dissolved in the bath at these high temperatures. Experiments with high chromium alloys were more successful and led to the adoption of compositions excluding nickel in which performance is guaranteed under constant use at temperatures up to 2350° F.

The voltage of the heating current varies with the size of the pot, the conductivity of the bath, and the nature of the work, but it usually ranges from 10 to 40 volts. It is convenient to have a transformer close to the pot, taking current from the regular plant circuits. In some of the latest installations two to four voltage taps are used, a higher one for capacity operation and lower ones for holding the bath in molten condition or for part-load operation.

One plant making novelties has provided taps for annealing stainless steel at 1850° F., another tap for annealing sterling silver at 1250° F., and a third for annealing nickel silver at 1450° F.

By placing ample insulation around the pot, heat loss through the walls may be reduced to a negligible amount. Under favorable conditions and after the bath has reached its working temperature, practically all of the electricity delivered to the pot is transformed directly into heating the work. In other words, the pot becomes a highly efficient furnace converting all the electricity into useful heat.

No electrolytic decomposition of the bath occurs because alternating current is used. The bath material is inert or neutral to the chromium alloy pot. There appears to be a slight attraction of the metallic walls of the pot for any non-metallic particles suspended in the bath, and as the bath operates these become attached to the pot so the bath becomes clear and transparent. The nature of these particles is such as to increase slightly the heat insulation so that the pot can be actually cooler than the bath under equilibrium working conditions.

Whereas one electrode in the bath was found to be sufficient for a small furnace, such as would be used in a tool room, the most natural procedure would be to use two or more electrodes for a larger furnace, connected in parallel and returning the electric current through the pot walls. In the early experimental work two immersed electrodes were accidentally connected in series. This arrangement had previously been considered but rejected because it was thought that the current would probably short-circuit to the pot. Even if this did not happen, the circuit between the two electrodes would be shorted if any metal parts submerged in the bath were to touch them.

Actually neither of these things happens and the use of a circuit from one electrode to another, all within the bath, seems to be the best solution for many salt bath heat treating problems. The electrical resistance of the melted salt is low, and there seems to be unusually large resistance at the surface of the contact between the electrode and the bath.

In most of the newest furnaces, designers have connected a resistance coil between two immersed electrodes in order to furnish a convenient means for heating from cold. When the bath comes up to the desired operating temperature, a proper resistance coil will carry less than 10% of the current.

On medium and large furnaces, say with pots 6 ft. long, and with ratings of 75 kw. per hr. and above, 3-phase current is usually supplied through three single-phase transformers, each one serving a pair of electrodes. In one specific case — a pot 28 ft. long, 3 ft. wide, and 3 ft. deep, with a rating of 600 kw. per hr. — six single-phase transformers, each rated at 100 kw., were used in this manner.

Economies due to internal heating are by no means confined to high heat treatments, as can be gathered from some details in connection with an installation now successfully operating in the bright annealing of steel wire. The pot is 5 ft. long, 4 ft. wide, and 4 ft. deep. Material is handled with yokes which hold up to 900 lb. of wire. The present practice calls for heating the wire in the bath for 15 min. at a temperature between 1250 and 1350° F. Bath material melts at about 1000° F., and the current input is so adjusted that a steady load of about 150 kw. per hr. is drawn. With this arrangement the equipment easily handles a ton of wire per hr. In sequence with this annealing are tanks of wash water and liquor or lime coating tanks, all arranged so that one operator can handle all operations from an overhead tram rail. This method produces wire uniformly annealed and free from scale. It has the important advantage of being flexible and sufficiently rapid to facilitate the prompt delivery of orders for a variety of sizes which present conditions seem always to demand.

High Heat Pot in Four-Pot Installation for Hardening High Speed Tools, Youngstown Sheet and Tube Co. Cool pot in left background is for quenching; two preheating pots (not shown) are in the same setting at right

Both seamless and welded tubing are now being successfully annealed in similar equipment. For this type of material it is desirable to secure a quick, clean, uniform anneal to facilitate further drawing to smaller sizes. A better quality of annealing has effected considerable savings through lowering of the rate of rejections, and annealing has become a regular step in the cleaning process.

Another very interesting and successful application is the annealing of sterling silver in bar form by immersing in a salt bath at 1250° F. One furnace installed during the past year now handles up to 900 lb. of sterling silver at a charge with the anneal cycle down to 7 min. The bars are charged on a rack directly from the rolling mill and are annealed and then quenched and are ready for re-rolling inside of 15 min. Here is a case where speed in handling a valuable product appreciably cuts down the capital invested in inventory.

For such products as forks and hollow ware, the saving through speed is frequently several times the cost of the annealing itself. This is due partly to the greater efficiency with which silversmiths work, and to the fact that this process is "fireless" in the terms of the trade. (The silversmith calls the usual oxide remaining after an annealing operation "fire," so the fact that he now has a furnace which gives a fireless anneal has a double significance.)

Cyanide hardening is another important application for this new method of heating salt baths. Here the full advan-

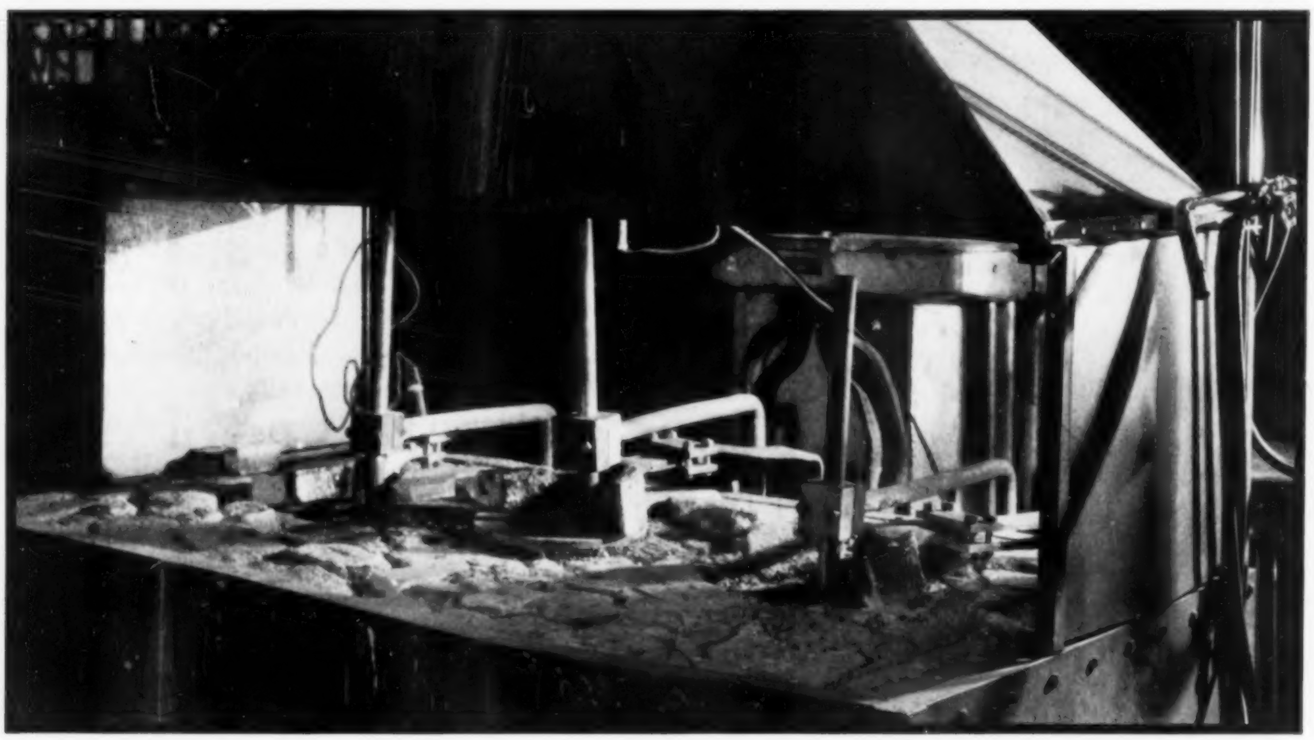
tage of long life of pot, of quick heating and automatic control of temperature, and the incidental elimination of dirt, flame, and noise is secured. The equipment may be readily installed near machines in a production line.

At the higher temperatures required for annealing stainless steel of the 18-8 variety (1900° F. and up), the lengthening of the life of the pot has been an important consideration. Several manufacturers of rods and wire, as well as others making finished products such as valve parts, tubing, cutlery, and surgical and dental instruments, are now using liquid salt baths for heat treating.

There are now a large number of special applications of internally heated salt baths in the high speed steel and alloy field, where troubles such as scaling, pitting, and dimensional changes have been eliminated to such an extent that some manufacturers have omitted final grinding operations.

Many cases of increased tool life are reported in the field of cutting tools heat treated in this way. One manufacturer reports 750 pieces threaded before regrinding of the tool, as against a maximum of about 400 pieces with tools hardened by former methods. In this case a furnace setting with four pots is used. The tools are preheated in the first pot at 1400° F., then transferred to the second pot which is operated at 1850° F., the third or high heat pot operates at 2300 to 2350° F., and the fourth or "quenching" pot at 1100° F. The heating current is fairly evenly divided between the first three pots (the fourth one being kept hot by the work quenched in it) so three single-phase transformers can be connected to a three-phase circuit. Such a unit with 25-kva. transformers can harden over 200 lb. of high speed hourly.

From these multiple units a very interesting heat recuperating and regenerating process has developed for such alloys as may be cooled by steps. It is obvious that where the same series of baths can be used for preheating and then for cooling (in the opposite direction), much heat can be economized. In fact, the electricity can be reduced in proportion to the number of pots used; two pots can recover about two-thirds of the heat, three can recover three-quarters, and so on. This high efficiency only is possible where there is rapid exchange of heat between the heating bath and the work, and where good insulation around the internally heated pot conserves the heat input.



Low, Intermediate and High Heat Pots at National Acme Co., Cleveland, for Hardening High Speed. Single electrodes and a three-phase transformer are used, the pots themselves being a common ground

BOOKS WORTH READING

General Metallurgy

THE PRINCIPLES OF METALLURGY, by D. M. Liddell and G. E. Doan. 626 pages, 6x9, maroon cloth binding. McGraw-Hill Book Co., New York. Price $5.50.

"PLANNED especially for the engineering student who will not require more than a general background in the subject, and as a compact, up-to-date reference for the practicing metallurgist."

This statement is printed on the jacket and a paraphrase of the authors' introduction and really represents an unattainable ideal. Failure is to be expected, but in failing the authors have created something far better. They have succeeded in compacting within 600 pages an account of the broad field of metallurgy from ore dressing to heat treatment and how the operations affect the mechanical and physical properties of the resulting metal.

In order to do this within small space it has been necessary for Messrs. Liddell and Doan to distill and double distill their own knowledge and the whole mass of metallurgical literature. This is stuff entirely too strong for the casual engineering student. It must be taken with understanding — one paragraph could be expanded into a chapter, one page into a lecture, and one section into a volume.

Mr. Liddell's part of the book comprises what may be roughly described as the chemistry of metals — the smelting and refining processes. Here, as through the whole book, the discussion is generalized; for instance, the *process* of "blast furnace smelting" is treated as the reduction of an ore-coke-flux mixture by an air stream, and is not a treatise on the manufacture of pig iron. Mr. Liddell's ripe experience enables him to warn the reader frequently that the economics of a specific operation may make a certain process practicable in one locality, whereas almost any other set of conditions would indicate a commercial (if not a metallurgical) failure.

Dr. Doan took that part of the broad field which he terms "metallics." To others it might be recognized as the physics of metals, or physical metallurgy. He approaches those vast and intricate problems of fabrication and use of metals and alloys from the standpoint of electrons and atoms. This is a logical approach for some minds, but most people are not accustomed to study their problems from the atomistic viewpoint. For instance, if a man were greatly annoyed by porosity in certain high alloy castings, and were convinced that a fine-grained structure would help, it would do him small good to read that "the atoms which first start to form crystals in a cooling melt probably are those in the lowest energy states of the Maxwellian distribution" (page 368).

This, of course, is a criticism of the mental limitations of the average metallurgist of today, rather than of the book under review. This second portion of it is actually a unique and up-to-the-minute summary of the whole new science of physical metallurgy. The trouble is not with Dr. Doan's presentation, but with his audience and with the science itself. As to the science — men have only recently and dimly appreciated the fundamental relationships between light, white aluminum and heavy, red copper, and the essential identity of the methods for hardening a steel blade and a lead cable sheath. It is remarkable that students and experimenters have been able to systematize as much as they have of the field of knowledge about metals and their alloys, and Dr. Doan is to be heartily congratulated on gathering together this vast mass of information (much of it available only in German publications) and restating it in a readable manner.

In fine, the book cannot be recommended to

a beginner, but can be, unreservedly, to any man working with metals whose mind is still in the inquisitive stage.

Stainless Steels

THE BOOK OF STAINLESS STEELS — corrosion resisting and heat resisting chromium alloys. Edited by Ernest E. Thum. 631 pages, 6x9 in., bound in red cloth. American Society for Steel Treating, Cleveland. Price $5.

A Review by H. M. BOYLSTON
Professor of Metallurgy, Case School of Applied Science

THIS is a veritable treasure house of information about these steels which have now been on the market long enough to determine that they have come to stay. Progress in their commercial development has been very rapid in the last few years and users and manufacturers alike, to say nothing of students old and young, will welcome to their library this information presented in such an authentic manner by over seventy experts from the industry. The book is a model of cooperative writing and has been brought together into unit form by its editor, who has also contributed an interesting historical and introductory note.

Beginning with the chapter on General Requirements and How They are Met, by Jerome Strauss, the book next describes the constitution of chromium and chromium-nickel steels by V. N. Krivobok. The problems of melting and casting are handled by A. L. Feild, R. D. Alger and G. C. McCormick, while rolling mill practice is ably handled by E. R. Johnson, Robert Sergeson, L. M. Curtiss, and H. D. Newell. Finishing and fabricating operations are described by some twelve experts, while welding is handled by such men as W. B. Miller, L. C. Bibber, V. W. Whitmer, E. J. W. Ragsdale and W. E. Smith. Articles on chromium plating are contributed by W. Blum of the Bureau of Standards and R. D. Zimmerman of the Ingersoll Rand Company. Bi-metal sheets are described by W. C. Johnson of the Plykrome Corporation.

Part II deals with properties of the typical alloys and such well known names as N. L. Mochel, E. C. Wright, A. C. Jones, O. K. Parmiter, J. P. Gill, W. M. Mitchell, E. R. Johnson, J. H. Parker, R. P. DeVries, C. E. MacQuigg, John A. Mathews, E. C. Bain, C. M. Johnson, H. D. Bubb and F. M. Becket are found in the list of authors in this section.

Part III deals with the requirements of the consuming industries with articles on principles and practice of corrosion testing, oxidation resistance and tests therefor, creep at high temperatures, and endurance — handled by such authors as F. N. Speller, N. B. Pilling, A. E. White and T. S. Fuller. The requirements of the chemical and food industries include such industries as petroleum refineries, heavy chemicals, paper mills, pharmaceuticals, dye manufacture, dairy and brewing industries.

The requirements of the metallurgical industries for heat treating equipment and the non-ferrous mining and smelting industry are dealt with while architectural uses, transportation industries and power industries come in for their share.

Part IV consists of a list of trade names of stainless, acid and heat resisting alloys made in America.

The printing is on calendered paper so that the many illustrations (about 290) show good detail and add to the artistic appearance of the well printed letter-press.

Iron-Silicon Alloys

THE ALLOYS OF IRON AND SILICON, by Earl S. Greiner, J. S. Marsh, and Bradley Stoughton. 457 pages, 6x9 in., bound in blue cloth. McGraw-Hill Book Co., New York. Price $5.

THIS is the second monograph issued by the Alloys of Iron Research under editorship of Frank T. Sisco, and is an admirable book in every respect. It is well written (sprightly diction describing even such matters as equilibrium diagrams!), well printed and illustrated. Much important tabular data are included, and useful facts are assembled from the available publications with discrimination.

About 200 pages are given over to a discussion of the structural and equilibrium diagrams of the iron, silicon, and carbon systems. This is not too much space, considering the complexity of the subject, and the fact that they are reasonably well worked out and may be taken as typical of other elements which raise the critical range in steels and graphitize cast irons.

About one-quarter of the remainder of the book is given to electrical sheet — possibly because of the fact that the senior author is in the Bell Telephone Laboratories. Notable chapters are also given to the "structural silicon steels" (which in America are not silicon steels at all, their strength coming from higher carbon and manganese), the silico-manganese spring steels, the 15% silicon-iron castings for corrosion resistance, and ferrosilicon.

Commercial alloy steels or irons containing silicon as the sole important alloying element are rather few, and hence a digest of the literature concerning them can be compressed into a couple of hundred pages. Silicon, of course, is an important auxiliary — it has a pronounced effect on the corrosion and heat resistance of the high chromium steels, and on the hardness and strength of the nickel steels. These matters are touched only briefly, they being doubtless reserved for volumes devoted to the major alloying elements. Likewise, the most important iron-silicon-carbon alloy of all — gray cast iron — is not noticed other than in the iron-graphite constitutional diagram; *that* would be the proper subject of a huge volume all of its own.

The present book should be of value to men interested in metal all the way from those who want to know how a ternary diagram is really worked out, to users of the present commercial alloys, and to those looking into the cheaper low alloy steels, where silicon and manganese replace the more expensive alloying metals of former years.

Design for Welding

PROCEDURE HANDBOOK OF ARC WELDING DESIGN AND PRACTICE. 434 pages, 6x9, flexible binding. Published by Lincoln Electric Co., Cleveland. Price $1.50.

PROBABLY the most interesting portion of this book is Part VIII — 90 pages, mostly of photographs showing all manner of welded constructions ranging in size from ships and oil tanks to torque tubes, and in rigidity from heavy presses to light ornamental iron work. If any designer, engineer, or manufacturer carefully inspects these illustrations, he cannot help but think he could use welding to advantage in his own work.

Taken as a whole, the book is most suggestive of the possibilities of welding. Take, for instance, a simple beam seat. The present book contains a number of sketches showing usable methods for beam connections. The designer may then make his own choice of an adequate detail, after estimating the comparative advantages for the problem in hand, both as to shop and field costs, and work out his own methods of figuring the details.

Another valuable section is the extensive tables of data on unit costs of welding various types and sizes of joints contained in Part III. These remove all guess from the estimate of cost per foot of seam.

Well-designed equipment and structures made of welded steel look so simple, so right, and so efficient that the danger of slavish copying is rather large. It is to be hoped that the second edition of the book will contain some desirable caution signals, calling attention to the absolute necessity of adequate engineering design as a preliminary to strict procedure control in the shop. Stress analysis in a simple beam seat, for instance, is not so easy!

OF GREAT value to any one who follows foreign literature is a good German dictionary. Of particular value to the metallurgist is a new one of metallurgical terms by Henry Freeman (*Deutsch-englisches Fachwörterbuch der Metallurgie*), published by Otto Spamer Verlag, Leipzig, and priced at 25 Rm. ($9.50).

In addition to the purely technical terms, this book gives the technical meaning of common words, which often takes a deal of imagination to puzzle out from the translations given in a general dictionary. One section of the book contains a long list of conversion factors (German to English and metric to English system) and a group of handy conversion tables for translating such things as kg. per sq.mm. into lb. per sq.in.

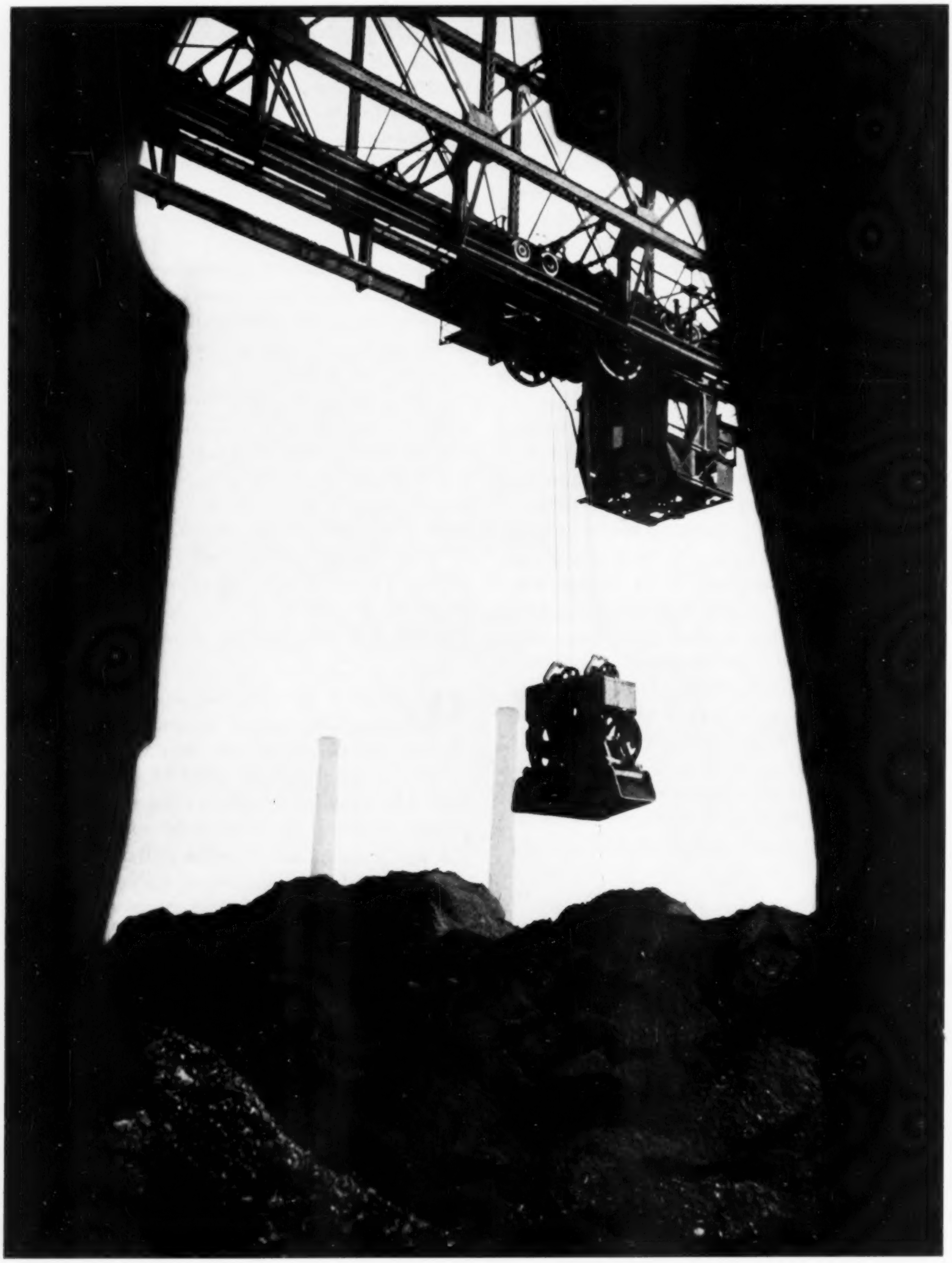


Photo by John Goski

Stock Pile

IMPORT MANGANESE ORE

for national insurance

An Editorial

SINCE THE SOVIET GOVERNMENT HAS been formally recognized by our own, it would seem that one obstacle for trade between the two countries is removed. Certainly such trade is desirable. Russia is sadly in need of buildings and machinery, and our "durable goods" industries are sadly in need of customers.

Apparently what we lack is a medium of exchange. Even though credit is offered and accepted, we know from recent experience that any large debt must eventually be paid in kind rather than in gold. But what can Russia send us that will not compete with our own industries and reduce employment of our own people?

About the only things that meet this specification are furs, platinum, gold, and manganese. Not knowing much about the first three, we can at least discuss the last, which is of great importance to the metal industry.

We have in the United States ample supplies of iron ore containing up to 11% manganese, but comparatively little *manganese* ore rich enough to smelt into ferromanganese. (Ten years ago a tariff equal to about 85% of the then value was slapped on ore, and this encouraged the mining of the most available ore so that by 1932 there were only five shippers who mined 9963 tons of ore.)

Nor have we any reserve of ore or ferromanganese. No less an authority than Mr. Farrell, former president of the U. S. Steel Corp., recently pointed out that our average stocks were only enough to supply the steel industry for four months, were ocean shipments to be interrupted.

Yet manganese is an essential commodity. We don't know how to make good steel without it. Over the last 20 years we have used it at the rate of 1 ton of 80% ferromanganese for every 140 tons of steel ingots and castings.

Under the circumstances, it would appear to be good business and an act of preparedness for Uncle Sam to contract with the Soviets for a quantity of manganese ore, import it, and stockpile it against the next emergency. It would not deteriorate on weathering nor is it subject to pilferage. It would be there when needed.

How much could we use?

During the last war our steel industry worked for four years at 90% of theoretical capacity. On that same basis, the next four-year war will take 250 million tons of steel; this needs 1,800,000 tons of ferromanganese (20 times our visible supply). Since it requires about 2 tons of 50% manganese ore to make one ton of 80% ferromanganese, we need a stockpile of 3,600,000 tons of ore.

It is now proposed that Uncle Sam contract immediately with the Soviets for this amount, to be delivered as rapidly as possible.

How much money will that mean for the

Russians? — or, put in another way: How much will this insurance cost us?

The price to be paid for such a large quantity of ore would be the result of negotiations. The price, f.o.b. Atlantic ports, of 50% ore just prior and just after the War was $12 to $14 per ton. After the duty was put on, the price jumped up, but has steadily declined since, the figures (less duty) sliding from about $21 in 1923 to $12 in 1932. In view of this history (and of some recent negotiations which all but succeeded), the Soviet government might be satisfied with $12 per ton, f.o.b. Crimean ports. On this basis their whole receipts for this order would be on the order of $43,000,000.

This, of course, isn't a great deal to pay for national insurance on a strategic material. Neither is it an overpowering amount for the Soviet government, which has already spent from 50 to 114 million dollars annually with us during 1924 to 1931, but it does represent twice as much as the value of goods we were willing to import from Russia in any one of those years. If a $43,000,000 credit, based on manganese ore, were available during 1934, it could doubtless result in the purchase of close to 100 million dollars worth of capital goods from our industries in that year. Not a small item!

The deal would be a good stroke of business, in view of the extraordinary prices asked for ferromanganese during the War.

Had we a similar stockpile then, we would have saved far more than its first cost. No one can know exactly what the excess cost of an inadequate supply of manganese was during 1916-18, but the $14 ore soared to $68.50 at the peak, and $70 ferro hit $400 a ton. The average surcharge on 266,000 tons of ferro used in 1916 was about $130 a ton, on 380,000 tons in 1917 was about $200 a ton, and on 352,000 tons in 1918 was about $150 a ton — in round numbers a total bill, due to unpreparedness in this one item, of $160,000,000.

We spent the money — plus a number of millions in an effort to get manganese at any price from our own deposits (and later repaid by the War Minerals Relief Act) — and still we have no reserves of this necessary metal! History will repeat itself unless we are forehanded.

A committee appointed by the American Institute of Mining and Metallurgical Engineers considered this whole problem at the request of the War Department in 1923 and again in 1931. Its published report discusses the problem thoroughly from many angles not possible in this brief article. It shows that the price of manganese metal in ore would have to go to about 4.7¢ per lb. before the stockpile now proposed could be won from our own scattered deposits. This would make the total cost $150,000,000 instead of $43,000,000, would gut the known American resources, and would take about 15 years to mine it. It is obvious that "probable ore" underground cannot be developed, mined, and shipped on a moment's notice.

It might lastly be inquired whether the Soviets have so much ore to ship. Unquestionably, their readily available ore reserves are enormous. The only question is their physical ability to produce the ore.

They say they exported 700,000 to 750,000 tons of washed ore containing about 50% manganese annually in 1929, 1930, and 1931. Probably this could be increased to 1,000,000 tons in 1934 and even more in subsequent years if a market were assured. Of this, something like 200,000 tons would be sent to customers in Europe and another 200,000 tons to usual importations by our own steel industry, leaving about 600,000 tons available for shipment to an American Government reserve. At best we could not expect them to deliver the 3,600,000 tons of ore in less than five years. This is not such a long time that the financing charges on the entire credit, made available promptly, would be burdensome.

Therefore, from every angle — expediency, security, economy, practicality — the proposal that our Government buy Soviet manganese ore liberally is worthy of active support.

One additional point may be raised, and that is that the ore should be converted promptly into ferromanganese rather than stored as such. Then the entire job would be done, and considerable stimulation given our own shipping and smelting industries. However, this matter of smelting the ore is secondary — the urgent thing is to *get the ore over here!* It would be a reliable national insurance policy for the future, and the present basis for a resurrection of export trade for our heavy industries.

HEATING OR ANNEALING

in controlled atmospheres

by R. J. Cowan
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Surface Combustion Corp.
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IN THE DEVELOPMENT OF THE IMproved heat treating machines necessary for the production of improved parts under more exacting conditions and at lower costs, one most important phase has been the study of the effect of furnace atmospheres on hot metals. These effects are quite independent of the source of heat, and the principles outlined below may be applied very broadly, although they have been studied as a part of a program for making gas available for these improved heat treating processes.

There are many applications where a controlled flue gas atmosphere surrounding the work will meet the requirements. Many other cases require a special atmosphere not consistent with direct combustion — a muffle must then be used to confine these atmospheres. We therefore have two broad divisions to consider — (*a*) heating in controlled flue gases and (*b*) heating in a special atmosphere contained in a muffle.

Controlled Flue Gases

Plain and alloy steel, copper, some of the low brasses, nickel, aluminum bronzes, and many of the rarer metals may be annealed in the controlled products of gaseous combustion and an effect produced that meets the usual industrial requirements. (It should be made clear at the beginning that the term "bright anneal" has so many meanings that it is readily misunderstood. "Bright anneal" may vary all the way from a result a little better than could have been obtained in an uncontrolled atmosphere, to a virgin metal surface of great brilliancy. On account of this flexibility of language it is better to deal specifically with particular cases and effects.)

In the heat treatment of steel in direct-fired furnaces there are two fundamental actions — scaling and decarburization — both increasing in importance as the temperature goes up. To determine the facts about different atmospheres commonly found in gas-fired furnaces, the American Gas Association has carried on at the University of Michigan an exhaustive series of studies. The work has been done by W. E. Jominy and associates, and results published as Bulletins by the University and as contributions to *Transactions*, A.S.S.T., where they should be studied by all who are deeply interested. The mass of data is far too great to be summarized in brief space.

One of the most difficult problems has been

the preventing of scale on metal heated to the high temperatures for forging. The common opinion has been that a highly reducing atmosphere is best (that is to say, one containing large amounts of carbon monoxide). Jominy has investigated this matter in detail and has outlined the procedure to be followed for best results. The Surface Combustion Corp., proceeding on different lines, has developed a particular type of gas burner that produces strata of air and gas, traveling parallel to each other throughout the furnace chamber without turbulence. Combustion occurs only at the surfaces where the gas and air are diffusing into each other, and grades from a perfect combustion mixture on down to conditions correct for breaking down the hydrocarbons into free carbon. This process of "diffusion combustion" was described in Metal Progress for September, 1932.

Scaling or decarburizing are two bad effects of open heating which may be avoided by controlling the atmosphere. Proper gas blankets will hold steel scale-free even at forging temperatures. Oxidation of brass or steel during annealing may be entirely prevented by special atmospheres. Others have been devised for producing a hard surface, either by carbon or nitrogen absorption

In many instances it has been difficult to establish a clear distinction between "luminous combustion" and "diffusion combustion," because diffusion combustion of certain gases is also highly luminous. In forging, for example, luminous combustion cannot produce scale-free forgings, whereas diffusion combustion can heat steel to forging temperatures without the formation of any scale whatever.

In the past year several noteworthy installations have been made which probably can best interpret the latter process. A valuable characteristic has been utilized, in connection with forge heating, to blanket the work with a stream of raw gas which completely prevents oxidation of polished steel even when heated as high as 2400° F. This gas blanket is maintained unbroken throughout the length of the furnace because of the non-turbulent or laminar flow from the burner.

A modification of this system of combustion has been used for introducing free carbon into the furnace atmosphere. This is valuable particularly in the case of sheets where it has been customary to use a charcoal dip to prevent sticking during rolling. When free carbon is injected into the furnace atmosphere the sheets do not stick together and surface conditions are good, even where a certain amount of air leaks through a poorly constructed furnace wall. In other words, free carbon in a furnace atmosphere offsets air infiltration which otherwise would have caused severe scaling in a non-luminous variety of furnace.

It has been possible in other cases (for example, on a car bottom annealing furnace) to offset a decarburizing effect by injecting a certain amount of free carbon. A wire normalizing furnace, where the wire is heated in coils to temperatures around 1900° F., meets the extremely difficult conditions of preventing detrimental scale on the outer strands of the coils and controlling the decarburization.

The importance and value of this control of free carbon in furnace atmosphere when handling steel at elevated temperatures cannot be overemphasized.

Jominy has also investigated very thoroughly the process of decarburization in gaseous atmospheres. In this instance also it was a surprise to find that hydrogen and carbon dioxide were so strongly decarburizing in their action, but it was a relief to know that these effects could be prevented by the presence of proper amounts of hydrocarbon and carbon monoxide gas. It is noteworthy that scale has an effect upon decarburization — usually of preventing it.

There have been conducted in the Surface Combustion Corp. laboratories, over a period of years, a large number of studies as to the effect of specific atmospheres upon specific

metals under different conditions. These have resulted in the development of a number of different processes for specific applications, using all the common industrial gases. It has been an interesting fact that the details of the application have often been of as great importance as the atmosphere itself and have demanded as careful a study as the mere chemical effects of the atmosphere itself on the metal under consideration. Under these circumstances it is obviously better to consider practical cases than to discuss generalities.

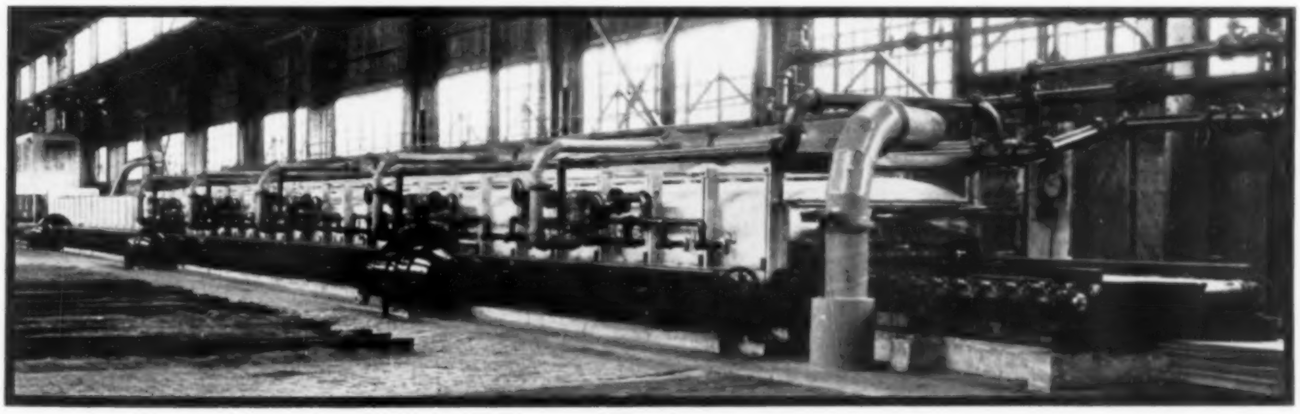
Many of the reactions involved are of a very specific nature that have to be conducted carefully to make them operative. For instance, when this work is done in a metal muffle, as it frequently has to be, the particular alloy used for the muffle or trays will have a very decided effect upon the reaction taking place. There are certain instances where a particular alloy is necessary to catalyze the desired reaction, whereas, in other instances, if the muffle is at all catalytic, the reaction takes place only on the walls of the muffle rather than upon the surface of metal to be heat treated! Such effects are baffling until the mechanism of the reactions is understood. By this means, hydrogen either from hydrocarbon or cracked ammonia may be catalyzed to produce unusual effects; also various organic compounds under the influence of an anti-catalyst may be so used.

The difficulty of heat treating copper-zinc alloys, usually included in the generic term "brass," is not great at low temperatures, but, as the temperature is increased to desired annealing temperatures and where zinc begins to volatilize from the surface, the difficulties are multiplied. Volatilization of zinc seems to be coincident with the liberation of occluded gases which oxidize the metal to a scale consisting either of zinc oxide or a mixture of oxides. The general problem was discussed by deCoriolis and Cowan in *Journal of Industrial and Engineering Chemistry* for 1929, page 1164.

Annealing of Brass

The usual method of approach to this problem has been to employ various atmospheres that are commonly considered neutral or reducing in their action. In gas-fired furnace technic the attempt has been made to use a flue gas purified of water vapor and carbon dioxide (since both of these are highly oxidizing to heated brass) to a residue of nitrogen containing small amounts of carbon monoxide. Such a gas has not succeeded in producing a bright-annealed brass, owing primarily to the oxidizing gases liberated from the metal itself.

In a contribution on this subject by the present author before the American Gas Association in Philadelphia, 1931, experimental evidence was presented to show that neither pure nitrogen nor pure carbon monoxide will prevent the staining and scaling of brass during the annealing process. The author was also able to prove that relatively small amounts of methanol vapor, even when added to atmospheres that were highly oxidizing to brass, acted as an inhibitor by some unknown mechanism



Controlled Atmosphere of Combustion Gases (Flue Gas) Is Successfully Used for Bright Annealing of Monel Metal and Nickel Sheet

and completely prevented the formation of oxide films.

In continuing the experimental investigation of these phenomena, it has been found that under proper conditions the bright annealing of metals, and particularly of brasses, can be accomplished in an atmosphere of hydrocarbon gases or any gas which will liberate hydrogen, or, in fact, hydrogen itself under properly controlled conditions.

When the heat treating operation is conducted in a muffle, the results are extremely interesting and valuable, especially where the operation can be made continuous as in the furnace shown opposite. When work enters at one end and discharges at the opposite end of an elongated muffle, a number of different reactions can be induced in successive zones, thus producing work of a uniformity and quality that can be obtained in no other way. This is due not only to the fact that the metal is subjected to successive temperature zones so that the work must receive identical heat treatment in passing through these zones, but also to the fact that temperature has a very great effect upon the reactions between metal surfaces and surrounding atmospheres. This brings about, in the different temperature zones, a desirable succession of chemical reactions.

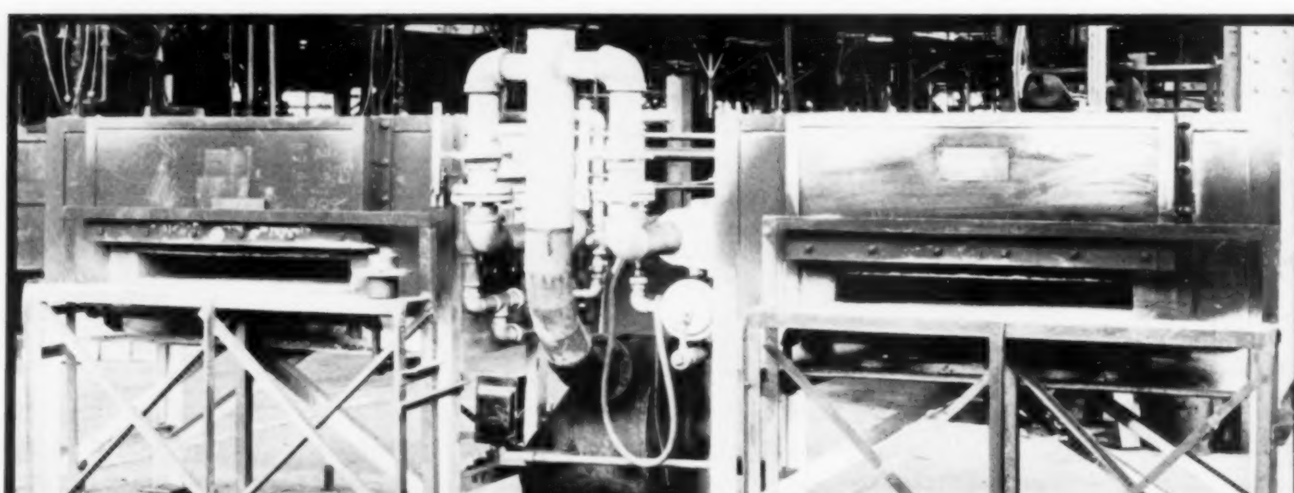
For instance, in the heat treatment of certain non-ferrous metals, an atmosphere may be found to be oxidizing in those temperature zones wherein the metal is approaching the full annealing temperature, and when this temperature has been reached, the oxide thus formed becomes a very active catalytic agent activating the atmosphere to a strong chemical effect upon the metal surface that has a very energetic cleaning action.

This same general idea might be illustrated by many applications on steels, and it is well to note one or two in particular.

Continuous Nitriding and Carburizing

Nitriding is done by subjecting a special steel to the action of ammonia. As is well known, a disturbing factor arises in that hydrogen is liberated from ammonia as well as nitrogen, and this hydrogen seriously retards and impairs the process, and is wasteful of ammonia. Nitriding has usually been conducted as a batch type operation and the above limitations apply to such an operation.

When it is conducted as a continuous process, unusual results have been obtained; for instance, ammonia may be used to 90% or 95% dissociation rather than the usual 35% to 40% dissociation as in the batch type operation. The time also has been reduced so that in 18 hr. a nitride case can be produced that is the equivalent of the usual 48 hr. case in the batch type



Diffusion Combustion Burners and a Blanket of Raw Gas to Immerse the Work Will Heat Steel to Forging Temperatures Free of Scale

of operation. By adjusting the temperature cycle, both the hardness and toughness of such a hardened surface can be affected advantageously.

It may be well to consider why this should be true. In continuous nitriding the work to be nitrided and the ammonia gas pass in the same direction through an elongated metal muffle. This means that while coming to temperature, the work is surrounded entirely by an atmosphere of concentrated ammonia gas, not yet broken down into its elements. Under these conditions it is impossible to have any accumulation of hydrogen, so that the injurious effects of this gas on hot steel are at once eliminated. As the metal gets hotter and hotter it acquires a preliminary hard case of nitride.

Yellow Brass, at Annealing Temperatures, Exudes Gases Which Oxidize Zinc. Bright annealing in continuous belt-type muffle furnace requires a special atmosphere containing methanol vapor, which stops this action

Since it has been firmly established that such a preliminary nitride case is not affected subsequently by an atmosphere of molecular hydrogen, this is a good illustration of the possibilities afforded by continuous operation whereby successive reactions of a desirable character may be brought about by means of proper atmosphere control.

Another illustration of these possibilities is afforded by gas carburizing.

The art of carburizing metals is one of the oldest of the metallurgical arts and from time immemorial has been conducted in a crude manner. While there have been some refinements in the process, the old method of packing the work in carburizing compound has maintained its predominance.

It has been generally admitted that carburizing is dependent upon reactions between gases and the steel, so that it would seem that a proper gas atmosphere would be most desirable for this work. Progress has been made along this line in the use of various hydrocarbon gases and mixtures of gases to produce the desired results. This has been an interesting development, but the complexity involved in the pyrolysis of hydrocarbon gases has made it difficult to carry on the operation without a great deal of care and attention. The limiting factors have been the deposition of free carbon and soot and the lack of uniformity of case.

The details of a continuous process in a controlled gas atmosphere were worked out in the laboratory by extensive experimentation, and a number of industrial installations have been made that are producing work of a very high quality and character. For a detailed description of one such, the reader is referred to METAL PROGRESS, February, 1932. The essential carburizing reactions are conducted in a series of successive reaction zones, and each piece to be carburized is made to pass through these zones in regular order. For this reason, each piece receives identical heat treatment in a succession of identical atmospheres that are under definite metallurgical control. Different carburizing effects may be obtained by varying the proportions of gases used in this operation. This makes it possible to produce either a hypo-eutectoid, a eutectoid, or a hyper-eutectoid case.

The regulation of this process is obtained simply by adjusting a couple of valves so as to maintain a flow of gas *(Continued on page 52)*

LETTERS FROM ABROAD

Oxygen Enriched Blast for Iron Smelting

GROSNY, U.S.S.R. — In the course of some development work on the fixation of atmospheric nitrogen, supervised by Prof. P. Checkin at the Soviet Nitrogen Institute, very important conclusions were reached concerning the utility of blast furnace gas for the manufacture of ammonia, after the normal air blast had been properly enriched with oxygen. These furnace experiments will doubtless interest metallurgists, for the desirability of oxygenated blast has been frequently pointed out, the basis being both theoretical computations and some tests made in Belgium in 1913 on a small iron furnace.

Prof. Checkin's proposal was unique. He argued that if cold air, enriched to about 50% oxygen, were blown into a blast furnace, the iron would come very fast and very hot. Immediately above the bosh steam could be injected into the superheated charge column, and the result should be a waste gas which would contain approximately three times as much hydrogen as nitrogen. After the CO and CO_2 had been absorbed, this waste gas of an iron-making operation would comprise the raw material for ammonia synthesis.

At first the idea was looked upon with apprehension by our metallurgists, they doubting whether smelting would take place under these bizarre conditions. So an experimental furnace was erected at the Chernovechensky chemical works in August, 1932. Dimensions of this furnace were: Hearth 5 ft. diameter by 4 ft. high; bosh expands to 5 ft. 8 in. at a level 12 ft. from the bottom of the hearth; total height 26 ft. 3 in.; effective volume 880 cu.ft.

The lining is made of magnesite brick one course thick (9 in.), and was built up within a sheet iron shell conforming generally to the interior lines. During operations, cooling water was sprayed all over this shell; no other coolers were used other than water-jacketed steel blocks around all necessary openings through the lining. Despite the very high temperatures (theoretically figured at 5800° F. and far above the melting point of the refractories) which existed for long periods in the smelting zone, this method of cooling was entirely satisfactory. At the end the lining showed no signs of excessive scour or melting. Neither was there any trouble with burned tuyeres.

After the furnace was well started, using air, a preliminary campaign was made on cold blast enriched to 35% oxygen. Later this was increased to 50%, and it was simply blown into the furnace without any additional protecting medium like steam. It is interesting to record that less cooling water was needed when the blast contained 50% oxygen than during the preliminary campaign. These findings were the result of a steady campaign of three weeks.

The high temperature in the hearth enabled the operators to make very hot cast iron, varying from 2 to 6% silicon. Coke consumption amounted to 1.5 ton per ton of iron, a value that was *less* as the oxygen in the blast increased. Slags were white in color (containing less than 1% FeO) and highly basic in nature. These came out very hot and liquid, yet were of a nature entirely impossible to tap out of an ordinary furnace on hot blast. Again, "semi-steel" containing as low as 1.25% carbon was formed, easily tapped and cast — another impossibility with a conventional furnace.

Generally speaking, the oxygen proved to be a very effective means for quick and easy regulation of the furnace. One can rapidly change a cold hearth into a very hot one; the operators therefore have no apprehensions regarding a slip of half-sintered material which has stuck to the lining.

The accompanying table gives the average composition, by volume, of the top gases, when the cold blast contains either 35 or 50% oxygen. It is seen that the general trend is toward a smaller volume of gas and smaller coke consumption per ton of pig iron as the blast is enriched more and more. Likewise the gas has a higher fuel value. The figures in the table may be compared with representative ones for hot blast coke furnaces of large size in America: Coke consumption 0.9 to 1.0 tons per ton of iron; 130,000 cu.ft. gas per ton of iron; CO content 21%, calorific value 90 B.t.u. per cu.ft.

Oxygen Enriched Blast Furnace

	35% Oxygen	50% Oxygen
Analysis of gas, by volume		
CO_2	15.4%	17.6%
CO	38.3	50.9
H_2	4.7	8.6
CH_4	0.4	0.6
N_2	41.2	21.8
Fuel value, B.t.u. per cu. ft.	150	210
Gas per ton of iron, cu. ft.	160,000	105,000
Coke per ton of iron	1.6 tons	1.5 tons

So much for the operation of this device as a blast furnace. As indicated at the outset, steam was blown in just above the bosh, and the top gas (for 50% oxygen cold blast) then analyzed 21.3% hydrogen and 16.5% nitrogen — a composition which remained unusually constant as long as the volume of blast and steam did not vary. Results were so encouraging that the Commissariat for Heavy Industries has authorized the construction of a larger blast furnace (7750 cu.ft. net stack volume) to produce gas for the nitrogen fixation plant. Its construction awaits a contract for adequate equipment for making the oxygen.

B. M. Suslov

Characteristics of Free-Cutting Steels for Hardening

Schweinfurt, Germany — In a letter last month I discussed the somewhat contradictory requirements as to machinability and heading properties demanded of cold drawn steels for automatics (screw stock). Since many parts cut from this material are later case hardened, the response to heat treatment is also another consideration. Uniformity of this property — shipment to shipment — is largely a matter of steel plant technique; of first importance is the deoxidizing practice during furnace refining, and second is the chemical composition of the steel. These in turn affect the important matters of grain size and stability (no change in tensile properties after aging).

A discussion of the refining of the bath just before tapping a heat of steel would take us far afield. It must suffice to say that it affects profoundly the response to the McQuaid-Ehn test (used to check the shipments) — that is to say, the character of the cementite network, its depth, the nature of the transition zone, the divorce of the pearlite, and the liability to harden with soft spots. Steels should be rejected if they are undoubtedly "abnormal" in the sense of this carburizing test.

Of course, it is possible to adapt a heat treatment schedule to the peculiarities of almost any steel that can be cast and rolled. But this is undesirable except as a last resort. A uniform delivery can be obtained if the steel producer sees to it that the metallurgical conditions in his furnace plant are constant.

The accompanying table gives the chemical limits of three automatic steels now widely used in Germany. In general, the silicon is most important in its effect upon machinability, while the hardening technique depends primarily upon the relation of carbon to manganese.

	Designation		
	LV 10	Sa_I	Sa_{II}
C	0.09 to 0.13	0.06 to 0.08	0.08 to 0.12
Mn	0.70 to 0.90	0.45 to 0.60	0.50 to 0.70
Si	max. 0.20	Traces	max. 0.20
P	0.09 to 0.13	0.06 to 0.09	0.06 to 0.09
S	0.08 to 0.15	0.150 to 0.200	0.150 to 0.180

The silicon content should be no more than a trace when emphasis is placed on obtaining the highest cutting speed (200 to 225 ft. per min.). If more emphasis is placed on good case hardenability and rivetability, steel with a maximum of 0.20% silicon is to be preferred, at the cost of reducing the machining speed to about ⅔ that of steels without silicon.

Manganese should be high enough, in high

sulphur and phosphorus steels, so that all the sulphur will combine to form manganese sulphide. The viscosity of the molten steel depends largely on the manganese content, and if it is over 0.50%, the metal will be thick, and gases and inclusions will not be easily evolved, so that gas blisters and pipe are more likely to occur. Sulphur and phosphorus, on the other hand, make the steel thin, so that, depending on these two impurities, manganese up to 0.90% can be used with advantage. If it is lower than 0.30 to 0.35%, it may be safely predicted that automatic steels with high sulphur and phosphorus will be red short. Therefore manganese under 0.35% is not sanctioned. This is particularly important for hot heading.

High manganese has the further effect of lowering the hardening temperature. A milder quenching medium can likewise be used, because manganese promotes the hardenability of the steel. This has a very favorable influence on the distortion of the section. All pieces up to quite large cross-sections with high manganese can be oil hardened, and, as is well known, oil hardening results in much less distortion than water hardening. In all cases considerable significance is attached to the selection of a suitable quenching medium.

High phosphorus content, up to 0.13%, has no detrimental influence on the heading properties, if the manganese and sulphur contents are within the prescribed limits, and if the molten steel has been killed by the addition of ferrosilicon, thereby also obtaining greater ductility.

As pointed out last month, the microstructure should be fine grained. It can have a segregated core or not, depending on the purpose for which it is intended and the type of subsequent fabrication. An optimum between high cutting speed (refined steel without silicon) and dependable case hardening (segregated silicon steel) must thus be the aim of every plant which hardens such materials.

For the ultimate service of the finished product, endurance strength is the most important property of all; in general, it depends on the stability, or the permanence of properties after aging.

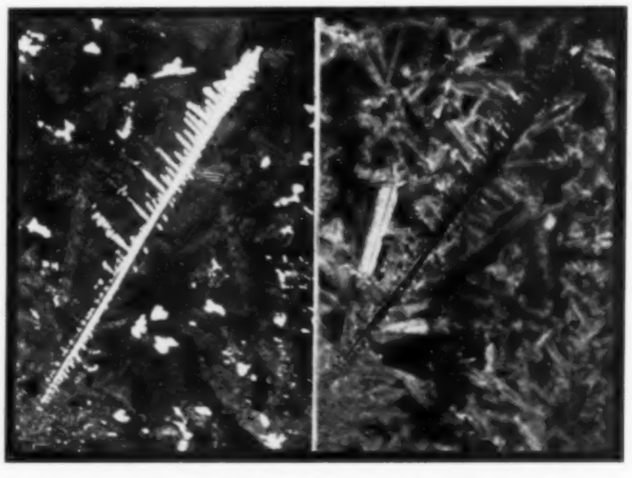
Now and then a rivet head will break off; others in the same service will hold, without any discoverable reason for this difference on the basis of tensile tests, elongation, or the usual microscopical investigations. It has been assumed that aging, due to phosphorus, oxygen, and nitrogen might be responsible. The latest investigations in this country indicate that phosphorus and oxygen are unlikely culprits. Studies on aging, therefore, are being directed more toward the effect of nitrogen, but we have not reached a clear conception of this matter.

H. DIERGARTEN

Inclusions Within Inclusions

PARIS, FRANCE — When applying the laws of physico-chemistry, we are wont to consider only the common phenomena to which we are accustomed, or those which have a practical application, thus forgetting that Nature disregards our individual desires and that its laws have no special concern in our interests. We like to consider molten metals and the slags that accompany them during the metallurgical operations as two non-soluble substances; everyday work shows them to be separated and non-miscible, and we take little or no notice of the mutual solubility which is required by the laws of two-phase chemical equilibrium.

The slag and the metal are, in fact, two non-miscible substances constituting such a system which approaches more or less closely a state of equilibrium according to the time allowed at the given temperature; but it is also true that true equilibrium modifies itself according to the tem-



Metallic Dendrite in a Complex, Crystallized Iron-Chromium Silicate Forming an Inclusion in a Chromium-Iron Alloy. Not etched, magnified 250 diameters. Vertical illumination at left, oblique lighting at right

perature and also to the changes in the concentration which take place in the two phases during solidification. Such a modification in true equilibrium involves some decrease or increase in the proportions of the phases present — every decrease of the slag phase, for instance, is equivalent to an absorption or a solution in the metallic phase. On the other hand, every increase in the slag phase involves a formation or a precipitation of non-metallics in the heart of the metallic phase.

In a letter to Metal Progress last May, the formation and evolution of non-metallic inclusions within the molten metal was discussed, and it was pointed out that these "sonims" appeared because the temperature changed and because of oxidizing or deoxidizing additions. An inclusion may therefore be considered as an "internal slag" dispersed in tiny particles.

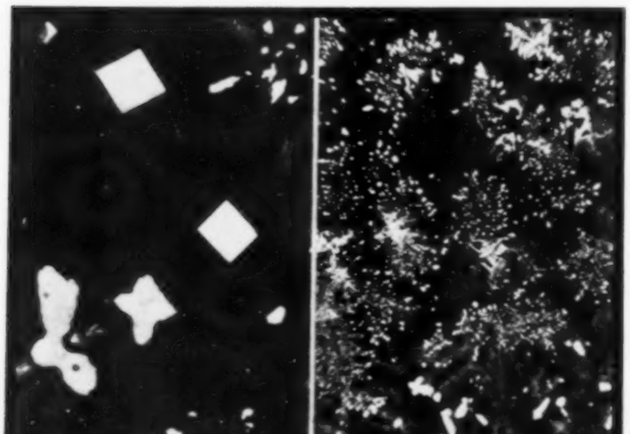
Such considerations have a more general value, and are by no means limited to the molten metal (in which we are more particularly interested because it is the material we are trying to obtain); they may also be applied to the slag phase that may either absorb or dissolve metal under proper conditions of temperature and composition — or, on the other hand, either precipitate some of this dissolved metal or give birth to some metallic inclusions. This is a phenomenon which is the reverse form of the one which has occupied so much attention from those interested in clean steel.

If the above is more than fine-spun theory, it must be possible to find some other inclusions in the heart of such non-metallic inclusions, and these will be particles of metal coming from some reactions within the slag phase, as it cools.

We are not aware that an observation of that kind has previously been recorded. Some examples will therefore be of interest, borrowed from a general study undertaken by the writer with M. Castro. We were investigating industrial steels and found some big inclusions in a low carbon stainless chromium-iron alloy containing 30% chromium. These inclusions were complex silicates of iron and chromium; *inside* them we found a metallic constituent presenting itself either in the form of dendrites, or of cubic crystals, or else of a eutectic cloud. The crystalline habit or appearance of such metallic inclusions, shown in the accompanying photomicrographs, and their behavior toward chemical reagents lead to the supposition that they are a chromium ferrite.

Metallic inclusions inside non-metallic inclusions seem a striking proof of the mutual solubility of the metal and slag phases, each in each, and of the precipitation of metallic crystals in the heart of a complex silicate.

Albert Portevin



Well-Formed Metallic Crystals, and a Eutectic Grouping of Metallic Particles Found in Complex Silicate Inclusions Within a Chromium-Iron Alloy. Not etched, magnified 750 and 125 diameters respectively

What Is a Weld?

Bethlehem, Pa. — Mr. Kinkead's appraisal of welding in December's Metal Progress justly deplores the lack of a broadly acceptable definition for the word *weld*. One was suggested in "The Principles of Metallurgy," by Liddell and the present writer:

"A weld is a joint maintained by the attractive forces acting between the atoms in one contact surface and those in the opposite contact surface, or between the atoms of these surfaces and those of an intermediate substance."

In mechanical joints, atomic attraction across the contact is not called into play. Scale or paint may coat the surfaces, or an air gap may intervene. The joint is maintained by the rigidity of the parts and connectors; atomic attraction across the joint is not required.

The phrase "or between the atoms of these surfaces and those of an intermediate substance" makes the definition of a weld include joints made by soldering and brazing, as is in-

deed inescapable. For the difference (say, in melting point or in chemical composition) between the metal of the parts joined and of the intermediate substance is always one of degree, varying from near identity in a flash weld, through alloy steel filler wires and bronze brazing wires, down to tin-lead solder. Hence brazed or soldered joints are types of welds.

If the definition were limited to a metallic joint, it would exclude joints in rubber, glass, wax, etc., in which atomic forces may operate across the joint.

Fusion welds, including thermit, arc, acetylene, atomic hydrogen, copper brazed joints, and others, all achieve the intimate contact necessary for atomic forces to act by having a part of the metal in the liquid state, the liquid part "wetting" the solid part and freezing to it upon solidification. The attraction between the once-liquid and the solid parts is an atomic attraction, frequently one acting across grain boundaries. This atomic attraction across contacting grain boundaries (likewise the attraction across a weld) is usually stronger than the cohesion of the grain itself. An intermediate amorphous cement, so called, may exist between the grains just as an intermediate substance may be present in a weld.

Pressure welds, including spot, butt, and forge welds, achieve intimate contact and atomic attraction by flow of the plastic metal at the joint to conform with the irregularities of the opposite contact surface, and by the squeezing out of obstructing films or scale. The welding of gold to lead by slow diffusion at room temperatures, and the cold welding of gold foil tamped into a dental cavity, show that heating is not an essential part of the welding process.

GILBERT E. DOAN

Cement-Sand Cores and Molds

TURIN, ITALY — The use of cement as a binding material for sand foundry molds has been adopted in Europe only recently. Opinions concerning its advantages are very divergent, according to the special conditions under which the first experiments were made.

It can be stated in a general way that the most satisfactory results have been obtained when cement has been used for very large molds, or for making cores of silica sand. In both cases very substantial savings have been obtained, owing to the fact that when using cement, the natural hardening of the mixture replaces drying in an oven or otherwise. However, many foundry superintendents object to the comparatively long time required for the cement to set, which means more or less delay in the regular output. This may be shortened by using the "quick setting" cements now on the market, and the best results have been obtained with high alumina fused cements.

From a purely technical point of view, the use of cement as a binding material has given excellent results. The castings are perfectly sound, and the high melting point of cement removes any danger that hot metal might fuse the mold's surface. The evolution of gases is very moderate and the castings are easily cleaned.

The proportions usually adopted in Italy for molds are: Sand 100 parts, cement 15 parts, water 10 to 12 parts.

While the actual saving when making molds in this way is limited to the drying operation, an additional saving on cores is due to the fact that cement replaces other more costly binding materials. The following data show the Italian cost of sand-cement cores, when compared with sand and linseed oil.

To make 1000 kg. of sand-cement core material would require 870 kg. of sand at 35 lira per ton, and 130 kg. of cement at 100 lira per ton, a total of 39 lira. The same weight of cores bound with linseed oil would require 982 kg. of sand and 18 kg. of oil at 1.70 lira per kg., a total cost of 65 lira.

If — in spite of this important saving — many foundrymen have not yet definitely adopted the new process in their core room, it is largely due to an indefinite sentiment, which could be phrased "the inborn distrust of limestone." In all instances where this "inborn distrust" has been overcome, either for evident theoretical reasons, or after definite practical experiments, the results have been excellent.

The only special precaution to be taken is when a certain proportion of old sand-cement must be used again. Necessary attention must be given to screening out the fine dust, and to proper ventilation of the premises.

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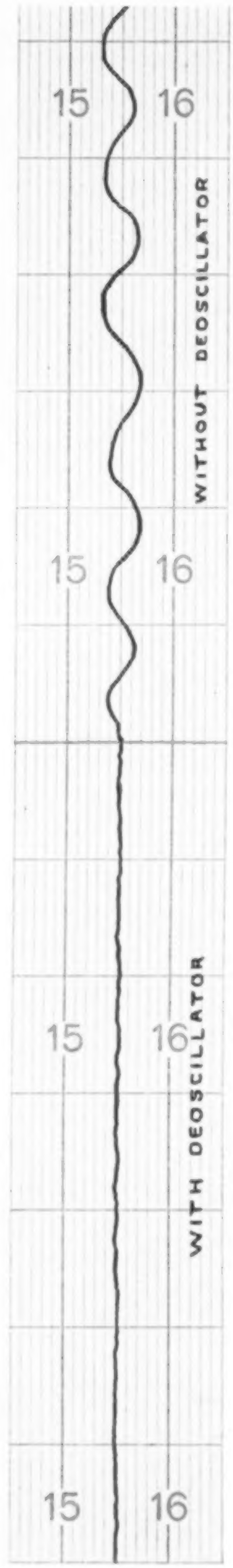

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(Continued on Page 50)

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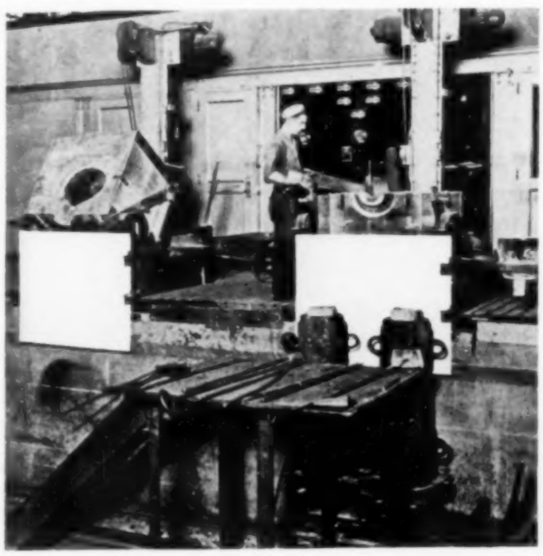

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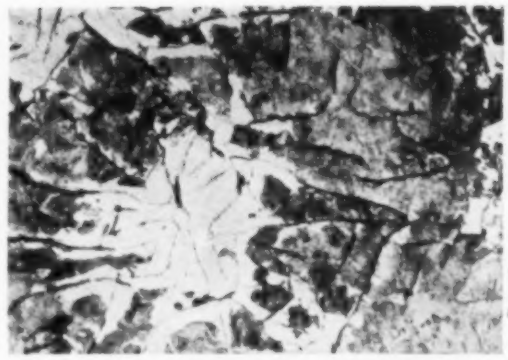

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These applications are the best illustrations that can be offered of the possibilities embraced in the use of a proper gas atmosphere for carrying on the different processes involved in the metallurgical art. Improvements are bound to continue and these improvements will revolve around the vast field of possibilities afforded by the intelligent application of correct atmospheres to particular problems.

It is necessary to sound a warning against all broad general claims as to these possibilities. The problems, for the most part, are specific problems that have to be met in a specific way, after a painstaking and thorough study of the fundamentals involved, and a correct engineering analysis to embrace these fundamentals in an industrial process that will fit the needs of shop operation. Thus the ideal of scientific operation without scientific supervision may be achieved. Only by this means will it be possible for the heat treat department to keep pace with the needs of industry and turn out a product of which all may be proud.